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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 107.

L. O. HOWARD, Entomologist and Chief of Bureau.

RESULTS OF THE ARTIFICIAL USE OF
THE WHITE-FUNGUS DISEASE
IN KANSAS:

WITH NOTES ON APPROVED METHODS OF
FIGHTING CHINCH BUGS.

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U. S. Department of Agriculture

BY

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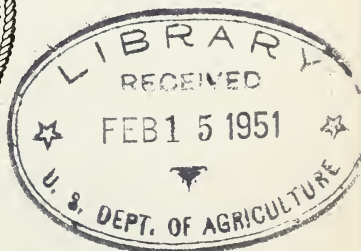
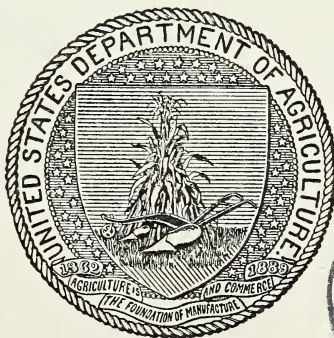
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ISSUED DECEMBER 21, 1911.



WASHINGTON:
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1911.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., August 17, 1911.

SIR: I have the honor to transmit herewith for publication a manuscript entitled "Results of the Artificial Use of the White-Fungus Disease in Kansas: With Notes on Approved Methods of Fighting Chinch Bugs," by Frederick H. Billings, associate professor of botany and bacteriology, and Pressley A. Glenn, assistant professor of entomology, University of Kansas.

The chinch-bug situation having become serious in Kansas, provision was made by the University of Kansas for the distribution of insects infected with the white fungus, *Sporotrichum globuliferum*.

The results of this work are embodied in the following pages, and I recommend the publication of this manuscript as Bulletin No. 107 of this bureau.

Respectfully,

C. L. MARLATT,
Acting Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

PREFATORY NOTE.

The chinch-bug situation having become serious in Kansas in 1909, provision was made by the University of Kansas for the distribution of diseased insects during the season of 1910 in accordance with the plan inaugurated by Dr. F. H. Snow during the nineties. The efficacy of this method of combating chinch bugs, however, has been questioned, not only by local investigators who gathered the field data for Dr. Snow's later reports, but by observers in other States, where, in most instances, the practice of distributing diseased bugs has been discontinued. While the demand of Kansas farmers for diseased bugs was granted, steps were taken to conduct an investigation of the problem of artificial distribution, not from the standpoint of proving or disproving Dr. Snow's theories as carried out in the nineties, but rather from the standpoint of practicability under present conditions.

The investigation was placed in charge of the writers, who began work in January, 1910, for the purpose of definitely settling the question as to the utility of continuing the work of artificial infection. It was felt that the seriousness of the situation to the farmers merited a stand that was based on many carefully collected data, so that future efforts might be urged along lines shown to be most efficient.

The writers of this bulletin wish to express their appreciation to Chancellor Frank Strong, whose continued interest in the investigations made them possible; to Profs. Stevens and Hunter for helpful suggestions; to Prof. Barber for the report of his work on chinch-bug inoculation; to Messrs. Leslie Kenoyer and Otto Opollo for their faithfulness in conducting experiments and taking observations near their respective homes; and to Messrs. E. O. G. Kelly, L. A. Kenoyer, and W. C. Bower for collecting weather data.

FREDERICK H. BILLINGS.
PRESSLEY A. GLENN.

UNIVERSITY OF KANSAS.

CONTENTS.

	Page.
Historical summary of chinch-bug diseases	7
Results of experiments for 10 years, 1888 to 1897.....	10
Outline of work against the chinch bug carried on in Kansas during 1910	14
Natural distribution of Sporotrichum in Kansas.....	16
Natural presence of Sporotrichum among chinch bugs during hibernation.....	17
Natural presence of Sporotrichum in wheat fields and cornfields during the spring and summer of 1910.....	18
Insects upon which Sporotrichum has been found.....	20
Natural distribution of Sporotrichum in the soil and its relation to artificial infection.....	20
Artificial infection experiments with Sporotrichum in the laboratory.....	21
Artificial infection—field experiments	26
Mr. L. A. Kenoyer's report of his experiments with Sporotrichum and the chinch bug	35
Remedial measures and conclusions.....	43
Bibliography.....	54

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Sterile jars filled with soil and chinch bugs, showing diseased bugs resulting from a spontaneous outbreak in the jar	16
II. Fig. 1.—Chinch bug enveloped in growth of the white fungus (<i>Sporotrichum globuliferum</i>). Figs. 2-7.—Dead chinch bugs, showing various degrees of envelopment in the white fungus.....	16
III. Various insects killed by the fungus diseases <i>Isaria</i> sp. and <i>Sporotrichum globuliferum</i>	20
IV. Various insects killed by the chinch-bug fungus, <i>Sporotrichum globuliferum</i>	20
V. Fig. 1.—Patch of corn protected by the oiled-straw barrier. Fig. 2.—Cornfield showing corn treated with crude oil.....	52

TEXT FIGURES.

FIG. 1. Map of Kansas, showing the number of packages of diseased chinch bugs sent out in 1910 by the University of Kansas to the different counties in the infested area.....	15
2. Map of Kansas, showing all the localities where <i>Sporotrichum</i> was found as a natural infection.....	19
3. Diagram illustrating the construction of the dust barrier.....	48
4. Diagram illustrating the oiled-ridge type of barrier.....	50

RESULTS OF THE ARTIFICIAL USE OF THE WHITE-FUNGUS DISEASE IN KANSAS, WITH APPROVED METHODS OF FIGHTING CHINCH BUGS.

HISTORICAL SUMMARY OF CHINCH-BUG DISEASES.

Since Dr. Snow, in his First and Sixth Reports of the Experiment Station of the University of Kansas, has given a somewhat extensive account of the chinch-bug disease prior to 1896, only a brief historical summary is deemed necessary in this bulletin.

Three chinch-bug diseases have engaged the attention of entomologists—a bacterial disease and two fungous diseases. What was at first supposed to be a bacterial disease was, on further investigation, ascertained to be only a normal condition in healthy bugs, so the two fungous diseases are the only true ones which have received attention.

One of the fungous diseases is due to a parasitic fungus, known to science as *Empusa aphidis*, and popularly known as the gray fungus, since it envelops the dead bug in a gray covering; the other is due to another parasitic fungus, known to science as *Sporotrichum globuliferum* and commonly known as the white fungus, since it envelops the dead bug in a white cottony mass. The latter is of special interest to us since it is the one which has been under investigation in Kansas.

The chinch bug was first noticed in North Carolina in 1783,^a In the Mississippi Valley it has been known since 1823.^b Since 1840 it has been under constant observation in Illinois and other States. It proved such a destructive pest from the first that entomologists have diligently sought for effective remedies by which its depredations could be avoided.

The first evidence of disease among chinch bugs was noted by Dr. Henry Shimer at Mount Carroll, Ill., in 1865.^c According to Dr. Shimer's notes, this outbreak was first noticed on low creek-bottom land, spreading gradually to the higher localities. The disease attacked both the old and the young, and was at its maximum during the moist, warm weather that followed the cold rains of June and the first part of July of that year. So complete was the destruction of the bugs that he wrote on August 8:

Scarcely one in a thousand of the vast hosts of young bugs observed in the middle of June yet remain alive, but plenty of dead ones may be seen every-

^a Fitch's Noxious Insects of New York, 1865.

^b Dr. Forbes's Insect Life, vol. 1, No. 8, p. 259.

^c See Bibliography, p. 54.

where lying on the ground, covered with the common mold of decomposing animal matter, and nothing else, even when examined by the microscope. Even of those that migrated to the cornfields a few weeks ago in such numbers as to cover the lower half of the cornstalks, very few are to be found remaining alive; but the ground around the base of the corn hills is almost literally covered with their moldering, decomposing bodies. This is a matter of so common occurrence as to be observed and often spoken of by the farmers. They are dead everywhere, not lying on the ground alone, but sticking to the blades and stalks of corn in great numbers, in all stages of development.

Entomologists were slow to accept Dr. Shimer's theory of an epidemic disease. Walsh and Riley ridiculed the idea, and Le Baron six years later declared that he knew of no predaceous parasitic enemies of the chinch bug. Later observations, however, confirmed the accuracy of Dr. Shimer's observations.

Evidence of disease among chinch bugs was not again reported until 1882, when Dr. S. A. Forbes, of Illinois,¹³ and Prof. Popenoe, of Kansas,¹¹ both reported localities in their respective States in which the bugs were dying with a fungus disease which embedded the dead bugs in a growth of white mold.

In August of the same year Dr. Forbes discovered what he thought was a bacterial disease due to a bacillus which he found in great numbers in the alimentary canal of dead bugs;¹⁰ but after a thorough investigation, which extended through several years, he ascertained that the presence of the bacillus was a normal condition in the alimentary canal of healthful chinch bugs,⁶³ and the theory of a bacterial disease was abandoned.

The fungus disease noted by Dr. Forbes and Prof. Popenoe was what is commonly known as the gray fungus, *Empusa aphidis*. What fungus was responsible for the disease among the bugs reported by Dr. Shimer can not be ascertained. The white fungus had not yet been detected. This fungus was first observed by Dr. Forbes in Clinton County, Ill., July 7, 1887, and again on August 7, 1888.^{36 54}

For more than a year this fungus affection was not found among chinch bugs, although a close watch was kept for it, but August 7, 1888, it was seen at Flora, in Clay County, fastening dead bugs to leaves of corn.

Almost simultaneously it was reported from Minnesota,³² Iowa,²⁷ Ohio, and Kansas.³⁵

It is worthy of note that no evidence of disease among chinch bugs was noted for about 80 years after the chinch bug became known as a serious pest, and it was 100 years after its first appearance that the white fungus was definitely recognized. It is also all the more remarkable in view of the prevalence of the disease over such a wide area at this time and during the years following. If these diseases were present among the bugs from the first, it seems strange that they were not detected earlier, and if they were in the process of introduction it seems strange that almost simultaneously they should be so plentiful in so many different, widely separated localities. It

is probable that they were present from the first, but because of the fact that they are so dependent upon the abundance of their host and upon favorable weather conditions they are not conspicuous except at intervals when conditions are just right.

In the years immediately following the discovery of the white fungus much attention was given to the investigation of chinch-bug diseases.

Dr. Lugger, of Minnesota, was the first to attempt to disseminate the disease by the distribution of diseased bugs. In October, 1888, he sent diseased bugs to various localities, and the experiment was apparently successful, as the bugs in these localities were found to be dying with the disease a little later. But the disease spread so rapidly that Dr. Lugger was led to suspect very strongly that the spores of the disease were already in these localities and that he had only reintroduced them, the spread of the disease being due to the spores that were already there rather than to the spores which he introduced.^{32 33}

Dr. Snow's observations and experiments in Kansas began in 1888 and extended through the season of 1896. In 1888 the chinch bugs disappeared from some of the eastern counties of the State during the months of May and June, and Dr. Snow expressed the belief that they were carried off by an epidemic.³⁵ Experimenting with the gray fungus, *Empusa aphidis*, he found that the disease could be communicated from diseased bugs to healthy ones by confining healthy bugs with the diseased ones. He also sent some diseased bugs to farmers and to agricultural experiment stations in Nebraska, Iowa, Missouri, Minnesota, Michigan, Indiana, Illinois, and Kentucky. The reports received from those who received the diseased bugs were very encouraging.⁶⁶

In 1890 chinch bugs in Kansas were very scarce, having been very generally exterminated in 1889.

In 1891 the legislature established an experiment station at the University of Kansas "to propagate the contagion, or infection, that is supposed to be destructive to chinch bugs, and furnish the same to farmers free of charge, under the direction of the chancellor, F. H. Snow."

During this period between 40,000 and 50,000 packages of the fungus were sent out to farmers, and extensive experiments were carried on in the laboratory and some in the field; the life history of the white fungus was worked out, and the best means of propagating it in large quantities ascertained. Observers were sent out from the station at various times to make observations in the field. The reports of these observers in 1891 and 1892 were very favorable, but in succeeding years the results of the observations were less favorable and brought to light the probability that the fungus was widely distributed naturally, since it seemed to be the rule rather than the

exception that the fungus was working as effectively in fields where none had been introduced as in fields where it had been artificially distributed. The fungus was found in every locality where the inspectors made observations. In commenting on this fact, Dr. Snow said:⁵⁶

Whether this widely extended natural presence of the *Sporotrichum* was the result of the general introduction of the infection throughout the State, in 1894, from the laboratory of this station it would not be possible with certainty either to affirm or deny.

A full account of Dr. Snow's work will be found in his six reports of the experiment station of the University of Kansas for the years 1891, 1892, 1893, 1894, 1895, and 1896. The following is taken from his last report:

RESULTS OF EXPERIMENTS FOR 10 YEARS, 1888-1897.⁵⁷

1. Chinch bugs in any of their stages of development scarcely run the slightest risk of death on account of heavy rains, even when these are of long duration. They are inconsiderably affected by extremes of heat and cold.

2. We know of no contagious bacterial disease of the chinch bug.

3. There are two parasitic, contagious, fungoid diseases that kill chinch bugs, namely, *Sporotrichum globuliferum* ("white fungus") and *Empusa aphidis* ("gray fungus").

4. These two diseases show their greatest virulence where the ground is damp and shaded from the direct rays of the sun and the air is humid.

5. We do not know to what extent the spores of these diseases are normally present in any given region. When they are present, whether naturally or artificially introduced, and the weather conditions are as given above, and the bugs are massed together, an outbreak of the diseases will occur. The number of chinch bugs killed in any field is approximately proportionate to the number of bugs in the field.

6. *Sporotrichum* can be artificially communicated to healthy chinch bugs, (a) It attacks bugs of all ages, but the older the bug the more easily does it succumb. (b) Bugs of any age that have been weakened from any cause, or injured, fall more easy victims to the disease than do those individuals that are in perfect condition. (c) The adults of the second brood, which, in the ordinary course of events, winter over and lay the eggs for the brood of the succeeding spring, are much more successful in resisting the disease than are the adults of the first brood. (d) The fungus is not active in winter, and, though it be present with the bugs in their winter quarters, they do not die of it, even though the winter be as mild and humid as was that of 1895-96.

The chinch bug seemed to have been almost exterminated in 1896 and there has not been any widespread outbreak since until the last two years, and hence little opportunity to investigate the practical value of the use of *Sporotrichum* until this year. Many requests for the fungus were received at the university last year, but no provision was made by the university to supply it until this year.

WORK IN OTHER STATES.

The method of combating chinch bugs by the artificial distribution of infection has been extensively used in other States, but in most cases the practice has been abandoned.

Dr. Lugger, who first attempted to disseminate the disease by means of distributing diseased bugs in 1888, adopted the plan again in 1895. In the First Annual Report of the State Entomologist of the State Experiment Station of Minnesota for the year 1895, he says:

Judging from the large number of letters, the writers were well pleased with the results of spreading spores among chinch bugs. * * * Of course it would be folly to claim that the disease was always spread by the introduction of such spores, and it is also possible that it would appear simply because the climatic conditions were in its favor. Whatever may be the reasons for its appearance, so many farmers believe in the effectiveness of introducing spores causing the disease that the State can well afford to continue this work.

However, the practice has been abandoned in Minnesota. Prof. F. L. Washburn, State entomologist, in Bulletin No. 77, Agricultural Experiment Station, 1902, says:

We do not know of any profitable means of killing the chinch bugs in the grain at present. In this connection we will say that the sending out of diseased chinch bugs has been abandoned, it having been found that the results were not sufficiently practical.

Dr. S. A. Forbes, who first definitely recognized the white fungus in 1887, began an extensive series of experiments with this and also the gray fungus, which lasted till 1896. The results of his investigations were not such as to lead him to recommend the use of the fungous diseases as a means of combating chinch bugs, although he was not ready to declare the method a failure. By isolating bugs sent in by farmers, he found that the disease developed among a large percentage of them without their being inoculated, and thus was led to conclude that the disease was very generally distributed naturally. In a series of field experiments he found that the disease was as prevalent in fields in which the fungus had not been introduced as in the fields in which it had been thoroughly distributed. Accounts of these experiments are recorded in the Sixteenth, Seventeenth, Eighteenth, Nineteenth, and Twentieth Reports of the State Entomologists of Illinois, 1888-1896. In the Twentieth Report he says:

Whether the fungi of contagious diseases can be artificially made use of to hasten or intensify the serviceable effect of favorable weather with a frequency or to an extent to make this procedure economically worth while, I am not yet prepared to say. The methods of distributing these fungi in the fields have hitherto been too crude to make their substantial failure conclusive as to the whole subject. It now seems quite clear that they can be at the best only used as a secondary to other measures, especially the midsummer measures described in the third article of this report. If applicable at all, however, they can be brought to bear at a point now entirely defenseless, and it seems the duty of American economic entomologists to spare no pains to investigate to a final and indisputable conclusion which promises so much as a remote possibility that the chinch bug may be attacked even to occasional advantage after it has settled itself in fields of small grain.

In Nebraska the fungus was used extensively in 1893, 1894, and 1901, but in the outbreaks of 1909 and 1910 the fungus was not recommended. To those asking for the fungus a circular was sent, which says in part:

It seems that the usefulness of this fungus disease as a method of destroying chinch bugs has been greatly overestimated by the farmers, since the experiments with it show that it spreads only when the weather conditions are just right—that is, when the temperature is somewhere between 70° and 80° F., and the air is very humid, and when bugs are massed in sufficient numbers that they come in contact with each other. When such conditions exist, the disease spreads rapidly and destroys the bugs very effectively, but under other conditions, especially in dry weather, the disease is quite ineffective. It is because of this extreme unreliability of the chinch-bug fungus disease, and its failure to spread when most sorely needed, that we have come to regard it as more of a detriment than a benefit in many cases, since it causes the farmer to place confidence in an unsafe measure to the neglect of more practical, though also more laborious, means of control.

The fungus was also used in Missouri, but has been discarded. Prof. J. M. Stedman ^a says:

A great many people send in to this office in the spring of the year for the chinch-bug disease, with the idea of scattering this disease about the fields of wheat and killing the chinch bugs infesting them. It is a fact that under certain climatic conditions this chinch-bug disease * * * will kill a great number of chinch bugs. But from seven years' experience with this disease in the wheat fields throughout the State of Missouri I am firmly convinced that the artificial use of this disease by the farmers of Missouri does very little, if any, good. * * * In the first place the chinch-bug disease is a natural one, found in nature, and is not an artificial one. * * *

* * * If the chinch bugs are in large numbers and the weather is hot and very moist, these spores will germinate on the bugs, and the fungus plant will kill them in great numbers. But if the weather is hot and dry, or too cool, although it may be moist enough, then the spores will not germinate, and no agriculturist has the power to bring about the proper conditions in his wheat or cornfield that will enable them to germinate. * * *

* * * I wish to say that it is very doubtful whether there is a wheat field or a cornfield in Missouri that does not naturally contain spores of this disease. I have been impressed with this fact every summer, because almost invariably, when the person applying for the chinch-bug disease sends to this office living chinch bugs that have been placed, as they should be, in a tin box containing no dirt, but some green vegetable matter, as for instance, pieces of green corn, wheat, or grass, and the box closed up as it should be, perfectly tight, thereby generating moisture in the box from these green vegetables, that by the time these bugs reach me the box contains more diseased fungus-covered bugs than we return; thus showing that the spores were already there in his field. * * * Knowing these facts, I can do no other than to conscientiously advise the farmers of Missouri not to trouble themselves with obtaining and scattering this disease about their fields, but to rely entirely, as they will ultimately have to do, upon nature to bring about the proper climatic conditions for the development of this disease in their fields.

^a Bulletin No. 51, Agr. Exp. Sta., University of Missouri, July, 1902.

Prof. F. M. Webster was one of the first to interest himself in the investigation of the fungus. As a special agent of the United States Department of Agriculture, located at La Fayette, Ind., he conducted some experiments which showed that moisture and a large number of bugs are essential factors in the successful propagation of the disease.³⁸ Later, as State entomologist of Ohio (now connected with the U. S. Bureau of Entomology), he experimented with the fungus in Ohio in 1895 and 1896. As 1895 was a dry season the fungus proved ineffective; but in 1896 the weather conditions were favorable, and Prof. Webster states:^{90 93}

I have always held to the opinion that the parasitic fungus *Sporotrichum globuliferum* could only be used in a manner to effect relief to the farmers during wet seasons and where there was a superabundance of host insects * * *. This year (1896) I can say with all conditions favorable, *Sporotrichum globuliferum* has done all that Dr. Snow or any other entomologist claims for it, but under conditions as adverse as these have been favorable the results will prove quite the reverse.

It would seem that Prof. Webster's subsequent observations have not materially changed his views; for he states in November, 1909:^a

As the fungus has many other host insects, it is probably present to a greater or less degree throughout the country every year. There is no doubt that during wet weather considerable benefit may be derived from the artificial cultivation and application of this fungus, but its efficiency is very dependent upon this meteorological condition, and, as has already been shown, chinch bugs develop in greater abundance in dry seasons. It will thus be seen that only during unusual seasons, that is to say, seasons that have been very dry while the chinch bugs were hatching from the egg, but wet afterwards, can satisfactory results be expected from this measure.

Thus it appears that the use of the fungus has not come into general use as a means of combating the chinch bug. Its use has been abandoned in nearly every State that has given it a good trial. Only three States sent out fungus during that season—Oklahoma, Ohio, and Kansas. Dr. Gossard, of Ohio, questions very seriously the wisdom of sending out the fungus and our investigations in Kansas this season, as the report shows, have made it certain that in Kansas at least the artificial distribution of the fungus is unnecessary. Its failure to come into general use may be ascribed to the following reasons:

1. The disease proves effective only during unusually wet seasons and when the bugs are very plentiful.
2. The disease is quite generally present in the field naturally.
3. Dependence on the fungus leads farmers to neglect other more practical means of control.

^a Circular No. 113, Bur. Ent., U. S. Dept. Agr., 1909.

OUTLINE OF WORK AGAINST THE CHINCH BUG CARRIED ON IN KANSAS
DURING 1910.

Owing to the presence of chinch bugs in destructive numbers over a considerable portion of the State in 1909, many requests were received for diseased bugs. The demands became so insistent that the regents of the University of Kansas made provisions for supplying the fungus to all applicants during the season of 1910. Following the methods used by the late Dr. Snow, a package of diseased bugs, accompanied by the necessary literature, was mailed to each applicant. The mailing list was primarily for residents of Kansas, but a number of farmers in Oklahoma were supplied with the fungus.

The literature consisted principally of a four-page folder, which contained, besides information for the use of the fungus, other information which was designed to enable the farmers to make intelligent observations in their own fields and to avail themselves of other methods of fighting chinch bugs.

It was understood that many authorities do not advocate the artificial use of *Sporotrichum*; still, in the absence of conclusive evidence to prove its impracticability, the recommendations of Dr. Snow in his last report were followed, with the hope that in the face of a threatened chinch-bug epidemic some good might result.

At the same time, however, provision was made for an investigation in order to determine definitely whether or not artificial infection accomplishes results sufficient to justify the labor and expense involved.

Work began early in 1910, some months before any infection was sent out. It was necessary to determine early which portions of the State were suited for carrying on experiments, judging from the number of bugs, and the extent of the distribution of the fungus naturally in the soil. Data as to the distribution of the fungus were regarded as more nearly conclusive if obtained before artificial distribution began.

No *Sporotrichum* had been distributed in Kansas since Dr. Snow distributed it from 1891 to 1896. Dr. Snow's reports show that the fungus was very generally present in the fields in 1895 and 1896, and on that account results derived from its artificial distribution were of doubtful benefit. This was thought to be a very favorable time for determining if the fungus had meanwhile maintained itself in the fields. Whether or not the fungus found in the soil at that time was the result of that sown by Dr. Snow years ago is, however, not pertinent to the problem, since the problem concerns itself with a plan of action for the present and future.

year, and become epidemic over large portions of this area in occasional years. The object of my experiments has been to artificially introduce the disease at times when they are not naturally raging in the fields. It was found in 1891 that there was no evidence of a natural existence of the three diseases in any part of the State of Kansas. This statement is abundantly substantiated by the detailed report of my field agent, Mr. Hickey, and by the reports of many farmers.

In his final report Dr. Snow makes this comment:

While no such general epidemic of *Sporotrichum* was noted in this year (1896) as occurred in 1895, yet the disease seemed present in those parts of the State visited, wherever favorable conditions existed, and in the fields, whether artificially infected or not.

It was therefore doubtless true that in the later years of Dr. Snow's campaign many spontaneous outbreaks occurred, and that conditions were perhaps not widely different from what they are to-day. Owing to a lack of scientific data, however, there is room for doubt as to the absence of *Sporotrichum* from Kansas soil prior to the recorded observations in 1891.

The investigations summarized in this paper had chiefly to do with the following problems:

1. Extent to which the white fungus disease of the chinch bug is naturally present in Kansas soil.
2. Practicability of artificial infection of fields in which the fungus disease is found to be naturally present.
3. Practicability of artificial infection of fields in which the fungus disease is shown to be scarce, or at least ineffective.
4. Experiments with barriers and insecticides.

Among other matters considered were (1) laboratory methods of propagating *Sporotrichum*; (2) artificial inoculation of chinch bugs with spores.

NATURAL DISTRIBUTION OF SPOROTRICHUM IN KANSAS.

In any investigation to determine the efficacy of artificial infection of a field with a parasitic fungus, the presence or absence of the fungus is one of the first points to be determined. If its absence be proved, a widespread persistent application of the infection might result in a considerable mortality of bugs, provided, of course, they are numerous enough to spread the contagion among themselves; but if the presence of the fungus is shown to be general, the problem resolves itself into that of attempting to improve natural conditions by artificial ones. Theoretically, at least, such a thing would be possible, but its practicability must be determined by actual experiment under a variety of conditions. It would have to be shown that enough bugs, beyond what naturally would have died, succumbed to the artificially sown fungus to make the effort worth while.



STERILE JARS FILLED WITH SOIL AND CHINCH BUGS, SHOWING DISEASED BUGS RESULTING FROM A SPONTANEOUS OUTBREAK IN THE JAR. (ORIGINAL.)

The white spots in the jars are fungus-covered bugs.



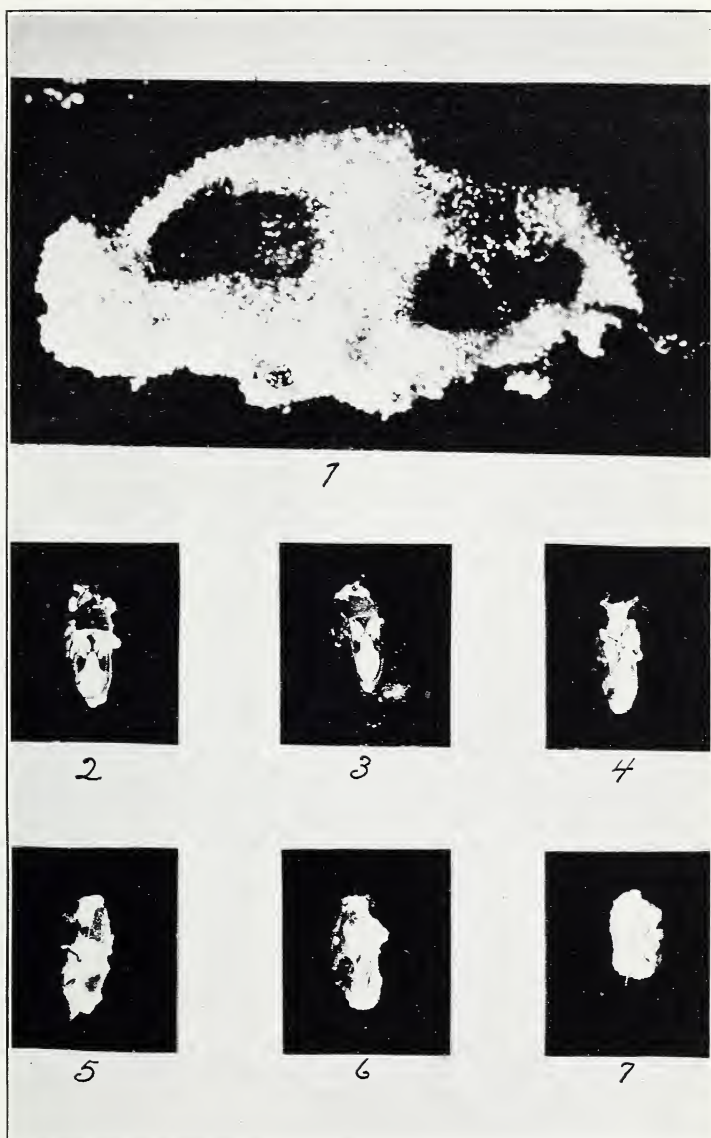


FIG. 1.—CHINCH BUG ENVELOPED IN GROWTH OF THE WHITE FUNGUS *SPOROTRICHUM GLOBULIFERUM*. FROM PHOTOMICROGRAPH ENLARGED X 22. (ORIGINAL.)

FIGS. 2-7.—DEAD CHINCH BUGS, SHOWING VARIOUS DEGREES OF ENVELOPMENT IN THE WHITE FUNGUS. FROM PHOTOGRAPHS ENLARGED X 7. (ORIGINAL.)



A spontaneous outbreak of the fungus in a field into which no fungus had been introduced would imply its natural presence there; and, conversely, its natural presence there would imply that a spontaneous outbreak would be possible, if given proper conditions. Hence it was determined to visit representative counties distributed through the infested area, and by examination of fields taken at random ascertain to what extent *Sporotrichum* is present in Kansas soil.

NATURAL PRESENCE OF SPOROTRICHUM AMONG CHINCH BUGS DURING HIBERNATION.

As conditions for the development of the chinch-bug disease were not favorable while the bugs were in hibernation, partly because of the cold or cool dry weather that prevailed and partly because of the resistant state of the insects, it was necessary to collect them and bring them into warm, moist surroundings, where, with increased activity, without food, their vitality would be diminished sufficiently for them to succumb to the attack of the disease.

The type of collecting jar adopted was an 8-ounce square bottle with wide mouth and metal screw top lined with cork. This was light in weight and packed well in a carrying case. Before taking a lot of bottles from the laboratory they were thoroughly sterilized in an autoclave. The tops were left loose during sterilization and then screwed down tightly upon removal, while hot, from the sterilizer.

After placing a number of bugs and a small quantity of earth in a bottle, by the use of sterilized tools, the lid was screwed down tightly and not removed until the bugs were dead, unless the soil in the bottle was too dry, in which case a little water was added, either from a near-by source in the field or else in the laboratory. If in the laboratory, precautions were taken against exposing the contents of the bottles to contamination. The tops were loosened and lifted on one side only, and then just enough to permit the entrance of a sterile pipette, filled with sterile water. By working expeditiously no more danger of contamination from the air resulted than in making transfers from one culture medium to another.

The favorite places for hibernation on the part of the chinch bugs, apparently, were the stools of the prairie grass, *Andropogon scoparius*. The grass was uprooted and some of the bugs placed in bottles by the use of sterile lifters. Several bottles of bugs, together with a portion of the surrounding earth, were collected in at least one locality in each county visited.

It was desired to ascertain if a spontaneous outbreak of the fungus could be obtained among the incarcerated bugs. Since, under the natural conditions to which the bugs were subjected in the bottles,

there was a possibility that the proper conditions might not be secured in some of them for the fungus to develop, the uncertainty was eliminated by having a number of bottles from each locality. *Sporotrichum* appeared in most of the bottles (see Pl. I), though its occurrence in but one of a series was sufficient to establish the certainty of its presence in the locality from which the collection had come. In some of the bottles no *Sporotrichum* developed. This was generally due to an excess of moisture which caused bugs to die before the *Sporotrichum* had time to make its presence manifest.

The chinch bugs in the bottles generally showed remarkable powers of endurance, as they were without food yet in warm surroundings. Some were found still crawling more than two months after collection and long after observations were taken. Some continued to live for this length of time with the *Sporotrichum* present and projecting conspicuously from dead bugs (see Pl. II) over which they frequently crawled.

Thirty-two counties in the infested area of Kansas were definitely shown to contain the white-fungus disease among the chinch bugs before egress from their winter quarters, during the latter part of March.

The first package of diseased bugs was sent out April 7 by the Kansas State Agricultural College at Manhattan. Five days later the University began its distribution of diseased bugs. It is therefore evident that *Sporotrichum* was present naturally in the localities examined and only needed the proper climatic conditions to break out spontaneously in the fields.

NATURAL PRESENCE OF SPOROTRICHUM IN WHEAT FIELDS AND CORN-FIELDS DURING THE SPRING AND SUMMER OF 1910.

Spontaneous outbreaks.—The chinch bugs left their winter quarters the last week in March, but owing to the dryness and coolness of April, no diseased bugs were found in the fields until late in the month. In the meantime the collecting of bugs and testing for the presence of the fungus continued. Later, when fungus-covered bugs were present in the fields, they were considered as direct evidence of its natural distribution, provided artificial distribution had not been resorted to.

Observations on the presence of *Sporotrichum* among chinch bugs in grain fields occupied the months of April, May, and June. During this time 27 additional counties were shown to contain the fungus. Summing up the work on the natural distribution of the fungus disease, it was found that 59 counties, which include most of the infested area of Kansas, showed evidence of its presence. Six counties, four of which were on the western edge of chinch-bug distribu-

tion, where excessive drought or else scarcity of bugs constituted the conditions met with, failed to show presence of *Sporotrichum*. Two counties, on the northeastern border, because of great scarcity of bugs, also failed to show signs of fungus. A few counties situated among

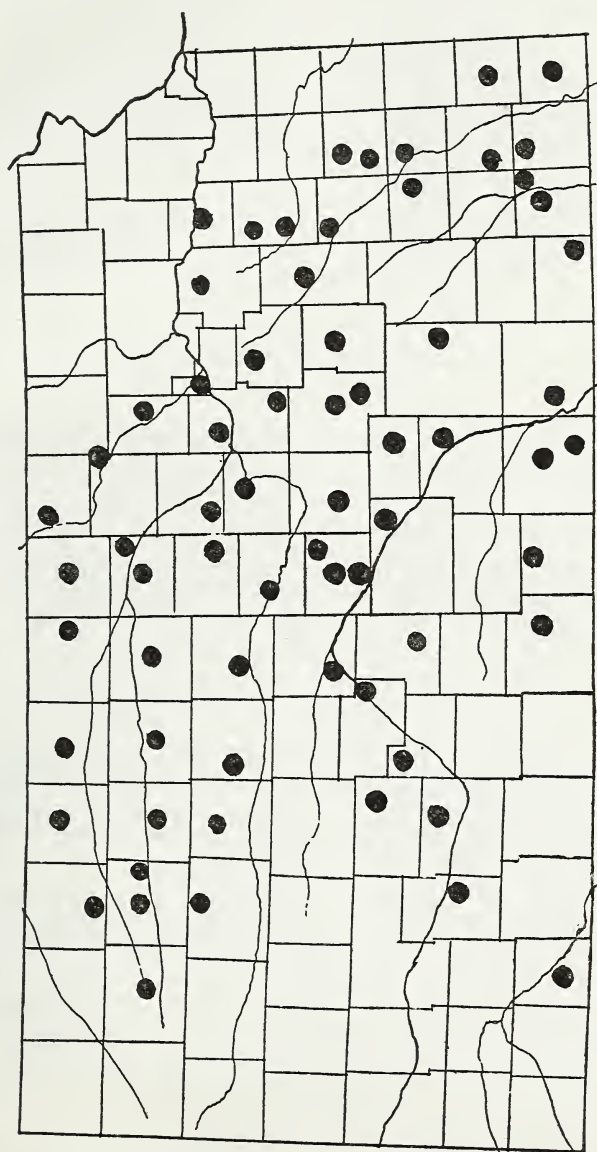


FIG. 2.—Map of Kansas, showing all the localities where *Sporotrichum* was found as a natural infection. (Original.)

others in which *Sporotrichum* was observed probably contained it, but, as they were not visited, no direct evidence was obtained. Granting its absence in such localities in 1910, however, it would be but a short time, owing to migration of the chinch bugs, before

spores from the adjacent counties would be carried over into every field where they might alight.

As will later be shown, *Sporotrichum* is not dependent on chinch bugs for hosts, but may live on other insects. There is hardly any question as to the presence of the fungus in the soil generally.

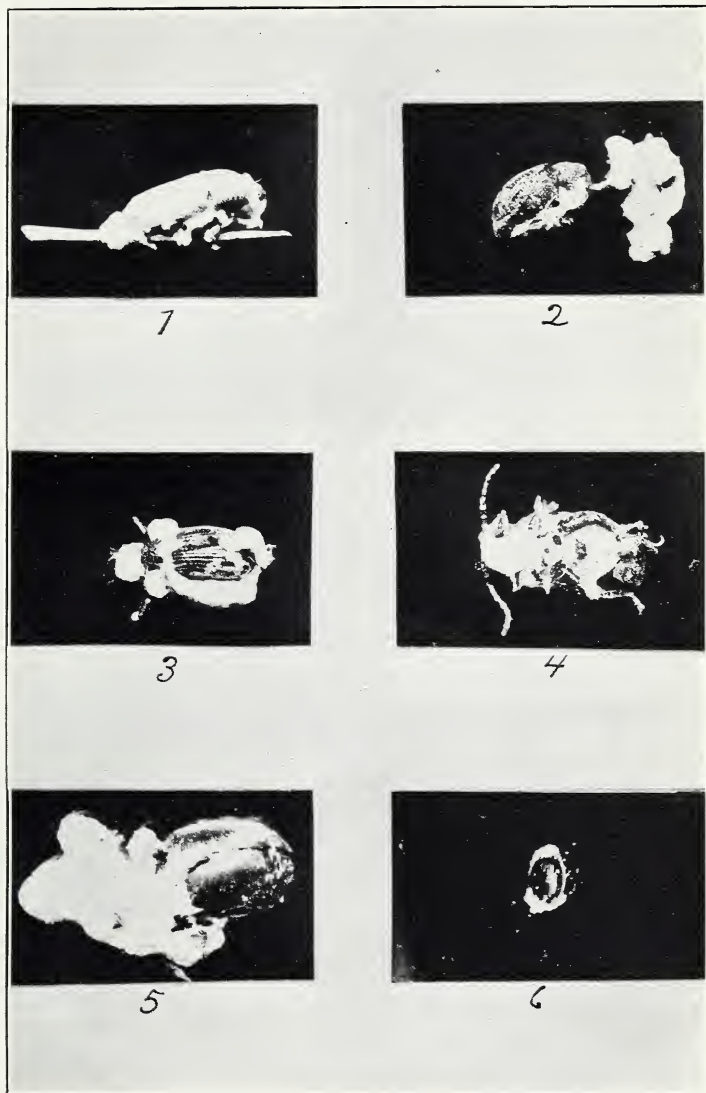
Maintenance of Sporotrichum in the soil.—From the ease with which *Sporotrichum* is cultivated in the laboratory at room temperature with dead organic substances as culture media, it is possible that it propagates itself, at times, saprophytically in the soil. It is not dependent, however, either on dead organic matter or on living chinch bugs, but may live as a parasite on other insects, some of which are present in Kansas as permanent fauna. Various writers from widely separated localities have reported *Sporotrichum* on insects other than chinch bugs. While making no attempt to search for the fungus on other than chinch bugs, the writers noticed insects from time to time displaying the characteristic *Sporotrichum* growth. A list of them is given below.

INSECTS UPON WHICH SPOROTRICHUM HAS BEEN FOUND.

Three common snout beetles, *Trichobaris texana*, *Conotrachelus erinaceus*, and *Anthonomus fulvus* (Pl. III, figs. 1, 2, and 3); a common flea-beetle, *Disonycha triangularis* (Pl. III, fig. 4); a very common lady-beetle, *Hippodamia convergens* (Pl. III, fig. 5); a minute beetle of the genus *Olibrus* (Pl. III, fig. 6); and three true bugs belonging to the same order (Hemiptera) as the chinch bug, one a rather rare insect, belonging to the family Phymatidæ, the species undetermined, and the other two common forms, *Microtoma carbonaria* and *Coriscus fesus* (Pl. IV, figs. 1, 2, and 3), and two unidentified larvæ (Pl. IV, figs. 5 and 6), and many common pentatomids.

NATURAL DISTRIBUTION OF SPOROTRICHUM IN THE SOIL AND ITS RELATION TO ARTIFICIAL INFECTION.

The general distribution of *Sporotrichum* naturally in the soil might affect the artificial use of the fungus in one of two ways—by rendering it unnecessary, or by making it more effective. In the former instance a spontaneous outbreak would occur, which, if conditions were right, would be of such magnitude that, whatever man might do in the way of artificially distributing fungus spores, nothing appreciable would be added to the results; or, given unfavorable conditions with a slight spontaneous outbreak, or none at all, artificial infection would not measurably spread the disease. In the second instance when there is already a spontaneous outbreak of considerable size, artificial infection might increase this to an epidemic that would end in a high percentage of mortality among the bugs. Other

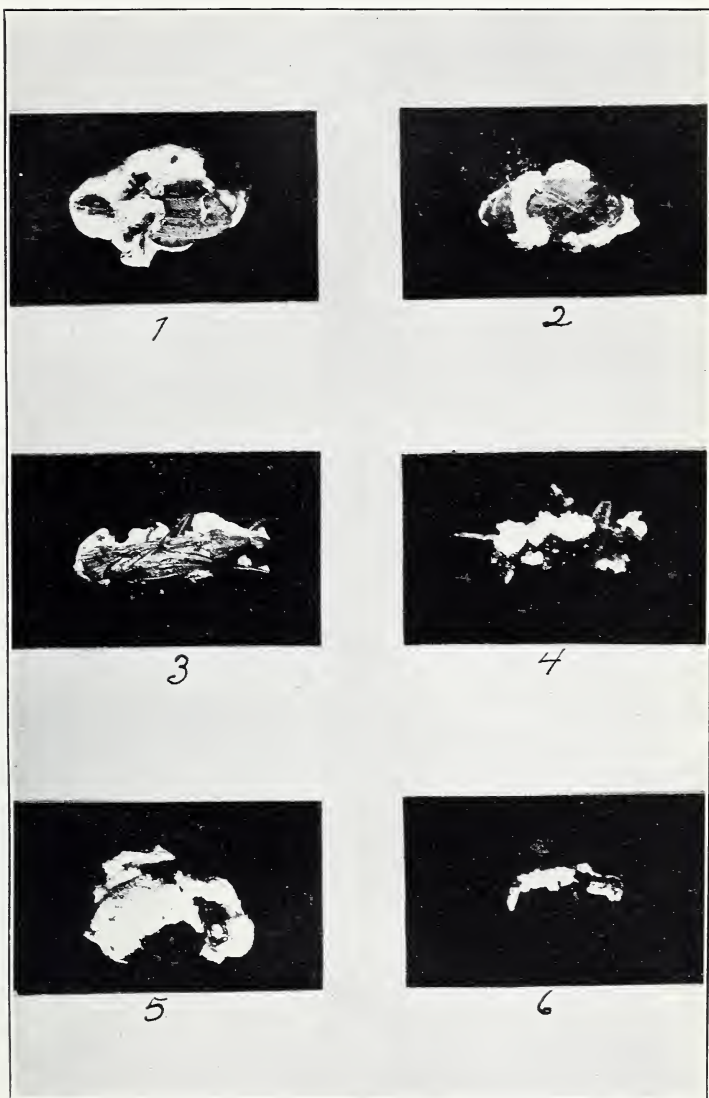


VARIOUS INSECTS KILLED BY FUNGUS DISEASES. NO. 2 IS *ISARIA* SP., THE OTHERS *SPOROTRICHUM*. (ORIGINAL.)

Fig. 1.—*Trichobaris texana*.
Fig. 2.—*Conotrachelus erinaceus*.
Fig. 3.—*Anthonomus fulvus*.

Fig. 4.—*Disonycha triangularis*.
Fig. 5.—*Hippodamia convergens*.
Fig. 6.—*Olibrus* sp.





VARIOUS INSECTS KILLED BY THE CHINCH-BUG FUNGUS, SPOROTRICHUM GLOBULIFERUM. (ORIGINAL.)

Fig. 1.—*Macrocephalus* sp.

Fig. 3.—*Coriscus fesus*.

Fig. 2.—*Microtoma atrata*.

Fig. 4.—*Coriscus fesus*, nymph.

Figs. 5 and 6.—Unidentified larvæ.



fields not artificially treated would then show merely a spontaneous outbreak with a lower percentage of mortality. The settlement of these problems was merely a matter of experiment under conditions that would cover possibilities mentioned above. As soon as spring opened and weather permitted, field investigations began; the purpose being to ascertain whether artificial treatment of a field infested by chinch bugs would prove profitable. One phase of the matter as described earlier in this paper had already been settled; the Sporotrichum disease was widespread naturally over the infested section of the State. It remained to be shown, first, whether sowing fungus spores in an already infested field would increase the epidemic, and, second, in a field showing but little evidence of Sporotrichum whether such a treatment would start an epidemic, otherwise improbable.

ARTIFICIAL INFECTION EXPERIMENTS WITH SPOROTRICHUM IN THE LABORATORY.

Preparatory to the field work it was found necessary to experiment with the fungus in the laboratory in order to determine the best method of propagation and the effect of the artificially grown cultures on chinch bugs. Quite definite results had already been obtained by Stevens, Barber, and Forbes, and advantage was taken of their conclusions, but at the same time it was thought best to experiment anew and adopt the methods best adapted to the experiments in hand.

Sporotrichum was first isolated from transfers made into nutrient agar from a chinch bug dead of the disease. Once obtained pure, there was no difficulty in propagating it on artificial media.

For field infection large quantities were needed, so that infection boxes which were designated for infecting bugs for distribution to farmers proved inadequate. The 10 c. m. petri dish used in bacteriological investigation was selected as the vessel in which to place the nutrient medium for growing the Sporotrichum. The fungus will grow on ordinary beef broth agar, but this was not found so useful as a combination of potato extract and corn meal.

Virulence of artificial cultures.—It was realized early in the investigation that the value of any work along lines of field infection depended upon a knowledge of the virulence of artificial cultures, since these were to be employed to a large extent. It was found that so much more fungus could be produced artificially with such certainty that diseased bugs, while used, were not depended on for the major part of the work. To test the virulence of the fungus, experiments were conducted at various times by artificially infecting chinch bugs with culture fungus (that grown on the potato-cornmeal medium) and then comparing results with others not so infected or infected by the use of diseased bugs.

Experiment 1.—This experiment was started April 29, the bugs being collected at Colony, a locality which showed an extraordinarily small amount of *Sporotrichum* in the soil when compared with other localities (except Garnett, in the same county). By selecting bugs from Colony it was hoped to avoid, as far as possible, the presence of spores on the bugs or in the soil before the experiment began. The insects were collected in five sterile bottles, with an approximately equal quantity in each. One bottle was infected with spores from an artificially grown culture. The other four bottles were not opened after they were sealed in the field. By May 13 three diseased bugs were noted in the infected bottle. Four days later all the bugs in the bottle were dead and about half of them were covered with a visible and typical growth of *Sporotrichum*. The bugs were dead in the four check bottles, but no fungus developed.

Experiment 2.—This experiment was designed to reach the same as the previous one, but by a different method. It began May 7. Six screw-capped bottles, each containing 100 grams of earth, were sterilized in an autoclave. Bugs direct from the field and not artificially infected were placed in three of them. To the other three bottles were added bugs, in approximately equal numbers, which had been allowed to crawl for two hours over a moist *Sporotrichum* culture.

Final observations were taken 10 days later. In the uninfected bottles no fungus developed. Two of the other three contained two and eight diseased bugs, respectively. No fungus appeared on the third. The short period of 10 days duration to an extent eliminated deaths by *Sporotrichum* resulting from extreme weakness due to prolonged incarceration and starvation.

Experiment 3.—This experiment was designed to compare the relative effectiveness of fungus grown on a culture medium and that arising naturally on chinch bugs. Thirty screw-capped bottles were prepared with 100 grams of soil in each bottle, then the whole was sterilized in the autoclave. About 18 chinch bugs were placed in each bottle. A sterile pair of forceps was used to transfer the bugs, and unsterilized field earth was avoided as far as possible. Bottles 1 to 10 were checks, No. 10 having no infected material added. Bottle 11 contained bugs which had been shaken up in a small box with three fungus-covered bugs which were finally added to the bottle before it was sealed. Bottle 12 was prepared in the same manner. Bottles 13–17 contained bugs that had been shaken up with a lot of crushed diseased bugs. Bottles 18–20 contained bugs that had been shaken up with soil which had previously been made infectious by rubbing up diseased bugs in it. Bottles 21–30 contained bugs that had been allowed to crawl over a mass of *Sporotrichum* grown on culture medium.

All bugs were collected at Cherryvale, a locality that showed an abundance of *Sporotrichum* in the soil; hence the positive results in the check bottles. The experiment began May 7, and by May 24 all the bugs in all the bottles were dead.

The results are tabulated below:

BOTTLES 1 TO 10.

Bottle No.....	1	2	3	4	5	6	7	8	9	10
Date.	Number of diseased bugs.									
May 10.....										
May 13.....	1									
May 16.....	1			1						
May 24.....	1	1	2	1	1		1	2		1

Total number of diseased bugs, 13.

BOTTLES 11 TO 20.

Bottle No.....	11	12	13	14	15	16	17	18	19	20
Date.	Number of diseased bugs.									
May 10.....	2					1	3		2	1
May 13.....	1	1	1	2	2	1		2		
May 16.....	1	2	1	2	2	1	2			4
May 24.....	1	1	6	4			1	1	1	4

Total number of diseased bugs, 53.

BOTTLES 21 TO 30.

Bottle No.....	21	22	23	24	25	26	27	28	29	30
Date.	Number of diseased bugs.									
May 10.....										
May 13.....	1	2			3	1	1	1		
May 16.....						2				
May 24.....	17	6	11	1	3	10	15	6	15	9

Total number of diseased bugs, 105.

It is possible that bottles 21-30 had more spores attached to them than those in the other bottles, but that the spores possessed virulence is shown by the results in mortality.

Experiment 4.—This experiment was begun May 17. Forty-eight screw-capped bottles, each containing an equal amount of earth, were sterilized in an autoclave. Twelve adult chinch bugs were then placed in each bottle. Twenty-four bottles were kept as checks (uninoculated), and 24 were inoculated as follows: Thirteen bottles by allowing bugs to crawl over spores from a culture and 11 bottles by scattering similar spores into the bottles with a camel's-hair brush. The brush was rolled in a mass of the spores in a petri-dish culture and then struck sharply against the lip of the bottle. A cloud

of spores was thereby dislodged, which so filled the bottle that every chinch bug must have come into contact with them.

On May 22 the results were as follows:

Bottle No.	1	2	3	4	5	6	7	8	9	10	11	12	13
	Number of diseased bugs.												
Inoculated.....	4	8	10	12	12	11	12	10	11	11	8	9	12
Checks.....	0	0	1	0	1	0	0	0	1	0	2	1	1

Bottle No.	14	15	16	17	18	19	20	21	22	23	24	Total.
	Number of diseased bugs.											
Inoculated.....	7	12	10	6	5	9	8	10	11	10	9	227
Checks.....	0	1	0	0	0	0	1	0	2	1	0	12

Experiment 5.—The last of the series on virulence was begun on July 14, this late date being selected for the reason that the cultures then in the laboratory had been running saprophytically since the original isolation of the fungus in January, 1910, and there was a question whether such prolonged cultivation on artificial media had had the effect of lowering the virulence and hence weakening the power of the fungus in attacking chinch bugs.

As the latter part of July was the time in which the field experiments were terminated, it was pertinent to know whether the fungus used in field inoculation during June and July had retained the parasitic nature evidenced by the earlier experiments of this series on virulence. Experiment 5 was arranged to compare inoculations with artificially grown fungus with natural infection. Natural infection was presupposed, since there was no field found where *Sporotrichum* did not exist naturally to some, even though to small, extent. The method of procedure differed but slightly from that in experiment 4. Forty screw-capped bottles were partially filled with 100 grams each of moistened and thoroughly mixed earth. They were then sterilized with 15 pounds pressure in an autoclave. Ten adult chinch bugs were placed in each bottle. Twenty bottles were infected by the camel's-hair brush method described in experiment 4. The other 20 were checks.

The bottles were watched, and it was soon noticed that *Sporotrichum* was appearing among the treated bugs at a much faster rate than among the untreated. The disease in the checks was undoubtedly introduced with the bugs and was present on them when they were collected from the field. But the same amount of natural fungus approximately would be present in the bugs in the inoculated bottles, so that final results would be but little affected.

The bottles were opened July 23 and the number of *Sporotrichum*-covered bugs ascertained.

CHECK BOTTLES.

Bottle No.....	1	2	3	4	5	6	7	8	9	10	11
Number of diseased bugs.....	0	1	0	0	0	0	0	0	1	1	1
Bottle No.....	12	13	14	15	16	17	18	19	20	Total.	
Number of diseased bugs.....	0	1	0	1	0	0	0	1	2		9

INOCULATED BOTTLES.

Bottle No.....	1	2	3	4	5	6	7	8	9	10	11
Number of diseased bugs.....	6	5	6	7	3	3	8	4	2	1	2
Bottle No.....	12	13	14	15	16	17	18	19	20	Total.	
Number of diseased bugs.....	1	1	1	0	1	2	0	4	6		63

The five experiments pointed uniformly to one conclusion—that no mistake had been made in adopting artificially grown fungus in preference to that found on dead bugs, especially when it was found that so much more could, with certainty, be procured. In a great majority of instances in which field inoculation was undertaken the natural presence of the diseased bugs in large amounts would have rendered ineffectual the scattering of the comparatively few bugs obtained from infection boxes.

Dr. M. A. Barber, director of the clinical laboratories of the university and inventor of the technique by which single bacterial cells or spores may be manipulated at will, conducted some inoculation experiments that shed light on the problem of virulence and infectiousness of artificial cultures. He has outlined his work below:

In the following experiments spores of *Sporotrichum globuliferum* were inoculated directly into the bodies of chinch bugs by means of very fine pointed pipettes made of hard Jena glass. Very small quantities of an emulsion of spores in salt solution were drawn into the tip of the pipette by means of a suction on a rubber tube attached to the blunt end of the pipette. The point of the pipette was then inserted into the leg or abdomen of the insect and the spores forced in by gently blowing into the rubber tube. Inoculation was done under a large simple lens. The same technique has been successfully used in the inoculation of flies, cockroaches, and other insects with bacteria and various microorganisms.

The experiments with chinch bugs were undertaken largely for the purpose of testing the technique, and the number of series undertaken

was too small to warrant any definite conclusions. The results, however, indicate that chinch bugs may survive the injury made by the pipette, that direct inoculation into the body is more surely followed by infection than exposure to spores placed only on the surface of the body, and that introduction of spores into the abdomen gives a larger proportion of infections than inoculation into the leg.

One series is given below as an example of the method employed. It differs, of course, from the natural one, but the technique is of service in testing the conditions of infection, as the virulence of spores grown artificially on culture media or the resistance of insects kept under different conditions or in different stages of growth.

All chinch bugs used in the experiments were taken from the same lot, and all were inoculated with an emulsion in physiological salt solution of spores of *Sporotrichum globuliferum* taken from a 21-day agar culture.

Twelve or more insects are included in each group. This culture was one derived from a series of transfers beginning with an original transfer made from a diseased chinch bug in January, 1910.

Group.	Inoculated May 26.	May 31.	June 2.	June 6.
1	In legs; at least contact of spores with injured surface.	No apparent fungus growth; some bugs still living.	Beginning of growth, apparently <i>Sporotrichum</i> ; growth first appearing on leg; all bugs dead.	Majority of bugs covered with <i>Sporotrichum</i> .
2	Spores placed on uninjured leg.	No fungus growth apparent; some bugs still living.	No fungus growth apparent; some bugs still living.	Several bugs with <i>Sporotrichum</i> ; some still living.
3	Inoculated in abdomen.	Beginning of fungus growth; all bugs dead.	All or nearly all covered with <i>Sporotrichum</i> .	Apparently all covered with <i>Sporotrichum</i> .
4	Controls; no spores added.	Apparently no infection; some bugs living.	Apparently no infection; some bugs living.	Apparently no infection; at least one bug living.

ARTIFICIAL INFECTION—FIELD EXPERIMENTS.

The fungus material used in the following experiments was grown in the laboratory by methods already described. In the field the dried petri-dish cultures were rubbed up with dry earth, making a mixture that was light-colored, due to the large admixture of spores. The mixture was dusted directly on the bugs on the infested wheat or corn, and on the ground at the base of wheat, where the insects congregated.

Shading experiments.—To test the effect of shade, artificially produced, on *Sporotrichum* in its parasitic relation to chinch bugs, small

plots of shade-giving, low-statured plants were set out in certain badly infested wheat fields. Shading experiments of a different nature were tried in cornfields, but these will be discussed in another place.

The plots were set out to beans or cowpeas, as the case might be (the former proving the better), and were 50 feet square. A row of beans a foot wide formed the four sides of the square, and four rows, each a foot wide, were planted across the square, 10 feet apart, so that they would intersect the wheat rows at right angles. The appearance of each plot when finished was that of a gridiron.

The original purpose was to provide such shade that chinch bugs traveling along the wheat rows would encounter the shade and the moisture conditions of the bean rows. The beans were planted thickly, so that when the plants grew to 8 or 10 inches in height the ground beneath them was moist when that elsewhere would be dry. It was hoped that the wheat would come into close connection with the bean rows, but this was not always the case. It was hoped, also, that the bugs would seek the shade, and thereby enter conditions which would favor the development of *Sporotrichum*. It was found, however, that the bugs did not collect under the beans to any extent, nor did they appear to pass across the rows except in a few instances. Hence the infection sown among the beans, or cowpeas, failed to gain a favorable opportunity to come into contact with the bugs. While as a shading experiment the bean plots were of no value, they served a most excellent use as areas of infection or centers of infection. As they were laid out directly in the wheat they contained chinch bugs in as great numbers as the wheat outside them. Fungus was sown in them in large amounts, so that one might expect one of two results: (1) The chinch bugs inclosed by the plots showing greater mortality by *Sporotrichum*; (2) the plots becoming centers of field infection, with the greatest effect seen nearest the plots themselves. In most instances the experimental areas exhibited spontaneous outbreaks of *Sporotrichum*, and, with the fungus sown artificially, the plots contained an extensive amount of infectious material. In each experimental field, where a 50 by 50 foot experimental area was inoculated with fungus spores, a check area, or plot, similar in every way, was laid out from 100 to 200 yards distant. By comparing the two plots the effect of the artificial infection could be judged better.

The spread of the disease, if any occurred, was watched not only in the experimental areas but in other parts of the field and in fields at distances from a fourth of a mile to several miles.

Artificial infection—Localities in which field experiments were conducted.—In the selection of fields for artificial infection the first prerequisite was the presence of large numbers of chinch bugs, since a contagion of any kind spreads faster, other things being equal,

where congestion is greatest. A second desideratum was the scattering of the centers of field work in such a manner that results would be general for the entire infested area of Kansas rather than local in character. Varied conditions would then be encountered; for example, one section would have less rainfall; another lighter soil; one with *Sporotrichum* abundant in the soil, another with it scarce. As to extremes of latitude, one county in the northern portion of the State and three along the southern border were chosen. With these things in mind, the following sections of the State, with the towns near which activities were carried on, were selected:

South-central section: Wellington, Sumner County.

Middle-central section: Newton, Harvey County.

North-central section: Lebanon, Smith County.

Southeastern section: Cherryvale and Independence, Montgomery County; Fredonia, Wilson County; Parsons, Labette County; Thayer, Neosho County.

Middle-eastern section: Colony and Garnett, Anderson County; Lebo, Coffey County.

Field notes covering observations made at intervals were, of course, carefully taken. Records of precipitation were furnished by a local or near-by observer in the Weather Bureau service. In a few instances rain gauges were provided and records kept for the immediate vicinity of the experimental farms.

The method of procedure in each locality was essentially the same. Until wheat harvest, artificial infection was confined principally to the wheat fields, though in a few instances oats and young corn, when badly infested, were also treated. Fields in which chinch bugs were particularly numerous were deemed best suited for artificial infection. Several such fields were generally selected, the owners' consent obtained, and either 50-foot plots laid out or inoculation made of some definite corner, side, or marked spot.

The experimental fields were examined before any infection was set out, to ascertain, if possible, the presence of the fungus naturally in the soil. Direct observation of fungus-covered bugs was one kind of evidence used. If these were lacking, as was the case earlier in the spring, when dry conditions prevailed over the entire State, sterile bottles filled with bugs and earth were used, with the expectation that the fungus would break out spontaneously on the bugs when in moist conditions under confinement. In almost every instance the experimental field was thus shown to contain *Sporotrichum* before any spores were sown artificially. The only reason for continuing with the artificial inoculation experiments was to determine whether the extra amount of infectious material added would induce an epidemic, when under normal conditions only a slight outbreak would occur.

Check fields, uninoculated and at distances varying from a quarter of a mile to several miles, were carefully observed, as they constituted the key to the situation.

It will not be necessary to give the field notes for all the localities in full, since a few will suffice to show how the work was conducted.

Sumner County.—Attention was first called to the vicinity of Wellington, in which chinch bugs promised to be extremely troublesome. Collections of the bugs early in the spring confirmed the report. *Sporotrichum* was known to be present in the soil because of its presence in the bottle culture used as tests.

The use of three wheat fields was kindly permitted by Messrs. Lynch, Banks, and Russell. Other farmers offered the use of their fields, but the three mentioned were found to be the most favorable in point of wheat prospects and numbers of bugs. The experiments on two of them will be described in detail.

Experiments in Mr. Lynch's field.—Two plots, 50 feet square and planted gridiron fashion, with a dwarf variety of beans, were set out about 150 yards apart in the wheat field northwest of the Lynch residence. The plots contained approximately the same number of bugs, but the wheat was ranker in one than in the other. It grew finally so tall and close that its shade greatly exceeded that given by the beans. The beans were sown in the latter part of April, but it was not until about May 18 that the plants were high enough to make sufficient shade. On May 18 the field was examined for chinch bugs dead of *Sporotrichum* that existed naturally in the soil. They were found in both plots; also in other parts of the field. The part selected for artificial infection was near the center of the field, by an old strawstack. The check plot was that containing the ranker growth of wheat. Owing to the shade in the check, the conditions for fungus development were deemed better, but, on the other hand, the plot with the thinner growth contained more spores, owing to the artificial infection. About 20 dried petri-dish cultures were stirred into a bucket of dry soil, and the mixture, whitened with the spores, was sown along the wheat rows and under the beans. There was no doubt but that the swarms of bugs around the wheat came into close contact with the infection. In addition, they jostled almost continuously the whitened corpses of bugs, already dead of the *Sporotrichum* disease.

A shading experiment, in which straw was used, was conducted near the infected spot. Small piles of straw were laid both between the wheat rows and around the wheat. Fungus-infected earth was then liberally sown in the straw and under it. The straw was utilized to keep the ground beneath moist, so that if bugs frequented the straw to any extent they would find conditions more favorable than out in the open. Many would contract the disease, perhaps, and then leaving the piles die in other locations, thus scattering the infection.

On May 25 a second and thorough infection of the previously infected plot and straw piles was made. At the same time results

of the previous inoculations were looked for and the general situation examined. Diseased bugs were found in both plots, more being found in the check. Recent rains that had moistened the soil now showed no effect on the surface, except where the wheat was rank. Bugs were dead in all parts of the field, and in many places the dead bugs were as numerous as in the infected plot. Under the straw that had been packed around the wheat there were more diseased bugs found than anywhere else; but there were no more, apparently, near the piles than at a distance from them, so that the infection had not spread, to any appreciable degree, at least.

Chinch bugs, young and old, swarmed along the wheat rows, with no more dead ones in the infected plot than outside of it, or in many other parts of the field. Clearly the artificial infection had yielded no results. The wheat was showing the effects of dry weather as well as the attacks of the bugs. It was found that the beans gave entirely negative results. While the ground remained moist longer beneath them, the chinch bugs did not frequent them to any extent.

On June 12 the Lynch field was again visited. The greatest number of living, as well as of diseased bugs, was found in the check plot, with its rank wheat. Conditions elsewhere were about as they were on the previous visit. The wheat had turned yellow and was nearly ready for harvesting. In the 25 days since the first infection in which the artificially sown fungus had been allowed to act, the moist conditions resulting from two periods of precipitation had favored the growth of *Sporotrichum*. On the whole, however, the period had been dry. The drought had not prevented a general spontaneous outbreak, but it probably checked its severity. The artificially infected plot had not only the bugs dead of the *Sporotrichum* naturally present, but it had relatively enormous quantities of culture fungus, so that as to intensity of infection it was much more thoroughly treated than would have ever been possible with diseased bugs, or than it would have been had the spores been spread over an entire field. The artificial inoculation was a failure in that it did not perceptibly decrease the number of bugs in the 50-foot plot, when compared with the area about it and with the check; nor did the fungus spread from the treated plot or the straw piles. The check had more diseased bugs than the treated plot, but this may have been due to the moister conditions produced by shade or to greater numbers in the first place. Apparently the presence or absence of the culture fungus did not affect the problem.

As check fields to the Lynch fields, three were examined, the nearest being about a fourth of a mile distant, the other two one-half and three-fourths of a mile distant, respectively. None had been artificially infected, yet each contained diseased bugs.

Experiments on Mr. Banks's place.—The field offered for experimental use was on a slope south of the house. Like the Lynch field, one had contained a rank growth and the other a thin stand of wheat; but the rank growth was denser and the thin growth was poorer than that found on Mr. Lynch's place. In order to balance matters the bean plot set out in the dense growth of wheat was used for artificial infection, while that in the thin growth served as a check. It was noticed that diseased chinch bugs were present in all parts of the field before any fungus had been distributed. The first inoculation was made May 18. Cultures were mixed with the earth and sown as in the Lynch field. The beans were useless, as they were shaded by the wheat. The ground was moist in both plots, and especially in the treated one. Observations were taken May 25. Both plots, as well as the remainder of the field, contained diseased bugs, but the dense growth showed the greatest number, outside the plot as well as inside. Had not the Lynch field served as a kind of control these results might have been regarded in part as favorable to artificial infection. On the same date (May 25) a second distribution of fungus was made in this plot. Final observations were taken June 12, but there was no change in the results. The favorable conditions of shade and moisture favored *Sporotrichum*. No matter whether fungus spores were added or not, about the same number of bugs died, and there were more than in a plot where the sun had a better access to the soil and where conditions were drier. The fungus showed no tendency to spread. The bugs had begun to migrate into the neighboring oats and the cornfields. A wheat field about a fourth of a mile distant, untreated, contained many diseased bugs. Other check fields were the Cann place and the Ruggles place, both about 3 miles distant. Diseased bugs were plentiful in all of them.

Weather conditions.—Statistics as to humidity and precipitation for the district around Wellington were kindly gathered by Mr. E. O. G. Kelly and his associate, the former an assistant in the Bureau of Entomology of the United States Department of Agriculture. The recording instruments were kept at the station, which was approximately the center of the area that would include the three experimental fields. Observations covered most of May and June, during which field investigations were going on. Total precipitation recorded by Mr. Kelly, 6.13 inches. The total for April, May, and June at Rome, a few miles south, was 6.27 inches.

The spring and early summer were unusually dry, as the average monthly rainfall for the district around Rome was lower than the normal by the following amounts: April, 1.59 inches; May, 1.23 inches; and June, 3.32 inches. In spite of the diminished precipitation, however, spontaneous outbreaks of *Sporotrichum* occurred all about Wellington, no field containing chinch bugs failing to exhibit the whitened, fungus-covered bugs.

North-central section, Smith County, Lebanon.—For this section Lebanon was selected as a favorable place for carrying on some field experiments. Accordingly, one of the writers went to Lebanon, April 18, and with the assistance of Dr. W. C. Bower and Mr. Charles Isom selected five fields in which to experiment. The details of the work in one field only, that of Charles Sargent, will be given, as the results in all these experiments were the same.

At the time of our visit it was very dry. On the 20th a severe dust storm prevented us from going to the country. The bugs were plentiful in all the fields visited, but no diseased bugs were found.

Experiments in Mr. Sargent's field.—On April 21 Mr. Sargent's field was examined for diseased bugs, but none was found, though living ones were abundant. On May 10 a supply of *Sporotrichum* was sent to Mr. Sargent with which to infect his field. On May 12 it was mixed with earth and distributed along a small draw where bugs were thick, wheat was rank, and moisture conditions were favorable. Small bunches of straw were also infected. The field was examined May 31 for results. Occasional dead bugs could be found in all parts of the field, but, on the whole, diseased insects were scarce. There were more of them, however, in the draw where the infection was placed than elsewhere, but this might have been caused quite as much by the more favorable conditions there as by artificial infection. There seemed to be a few more diseased bugs also in the immediate vicinity of the bunches of straw than at a distance of a few yards away, but the difference was so slight that the experiment could scarcely be called successful. On the same date Mr. Moore's field, 1 mile south, and Mr. Waddles's field, 1 mile north, were inspected, and diseased bugs were found in both of them, though they had not been infected artificially. There was no appreciable difference in respect to the number of dead bugs in the fields.

On this date (May 31) a second distribution of fungus was made in the draw. Spores were dusted directly from the cultures upon the bases of the wheat, where the bugs were most plentiful. This was done in two definite areas, which were carefully marked.

During wheat harvest, June 28, the field was again visited. Diseased bugs were much more numerous all over the field than at the time of the previous visit. Especially was this true along the draw where in some spots the diseased bugs were thick enough to whiten the ground. In and around the two infected spots, however, there were no more diseased bugs than in equally favorable spots elsewhere. Young bugs were still swarming in the wheat in vast multitudes, so that the fungus did not materially help the field, though a good many died, especially among the old bugs. Two factors may have been at work in the outbreak of *Sporotrichum*; one, the artificial infection, the other, the favorable conditions acting in conjunction with the

fungus naturally present in the soil. In analyzing the factors, the distribution of the dead bugs was taken to be the important element. A search of the field showed that they were thicker in some parts than in others, but numbers were related to conditions of moisture rather than to centers of artificial infection. Hence it is not improbable that the situation would not have been appreciably altered had no fungus been sown in the field. Other fields near Lebanon in which no *Sporotrichum* had been introduced, or at least not until a later date, were used as checks, and particularly the Moore field, 1 mile south, and the Waddles field, 1 mile north. They were examined carefully on the same dates as the Sargent field, and at no time was there any perceptible difference, so far as diseased bugs were concerned, in the three fields. All the check fields contained diseased bugs in considerable numbers, especially where the conditions were particularly favorable. Owing to artificial infection of the Sargent field before the time was ripe for a general spontaneous outbreak of *Sporotrichum*, the occurrence of the outbreak in this field had all the appearance of being due to the sowing of the fungus. To a casual observer the success of artificial infection would have been regarded as indisputable, though of course partial, since not all the chinch bugs were killed. It is likely that some of the "successes" reported by farmers in former years were due to a misinterpretation of such appearances of *Sporotrichum* among the bugs.

The results of the experiments at Lebanon showed the importance of moisture conditions as factors in the development of the *Sporotrichum* disease, especially in a dry season, and at the same time how unimportant a factor is the sowing of the fungus spores.

Total precipitation at Lebanon for the months of April, May, and June, 1910, 6.85 inches, which was 2.08 inches less than the average. For May, however, the rainfall was 0.04 inch greater than the average. The greatest deficiency in precipitation was during April.

Southeastern section, Montgomery County, Cherryvale.—Three farmers near Cherryvale kindly offered the use of their wheat fields for experimentation. They were Mr. Metcalf, Mr. Benham, and Mr. Darling. The vicinity of Cherryvale was badly infested with bugs and hence offered a favorable opportunity for experiment. The eastern portion of the State, moreover, exhibited better climatic conditions, owing to greater rainfall and humidity.

On April 27 collection of bugs and earth in sterile jars was made from each of the three fields mentioned above. *Sporotrichum* developed readily, thus showing the presence of the fungus naturally in the soil. On the Benham and Darling places, 50-foot plots of the usual type were set out to cowpeas and placed about 100 yards apart.

The cowpeas did not prove of any advantage as to shade, and so the plots were used to mark the areas for infection and check.

Experiments in Mr. Metcalf's field.—This field was located about 4 miles north of town and was the worst infested place seen around Cherryvale. No plots were set out, but the infection of it was left in the hands of Mr. Metcalf himself, who scattered the fungus generally over the field. On May 2 a large package of fungus culture was shipped, with instructions as to mixing with soil and distributing through his field. On May 13 a second lot was sent, and a third shipment was made May 22.

On May 26 a visit was made to the field. Up to this time there had been two artificial distributions of the fungus culture, and also several of diseased chinch bugs taken from an infection box. Living bugs were exceedingly numerous, and the conditions for their destruction by *Sporotrichum* were to all appearances ideal, as rainfall, a moisture-retaining soil, and high humidity for much of the time conspired to render the spread of the fungus easy. An outbreak of *Sporotrichum* occurred early in May, and by May 26 had succeeded in killing many thousands of chinch bugs, so that they were plainly in evidence on the ground all over the field, yet so numerous were the living ones that the dead ones were at any time only a small percentage. Had not the check fields been watched, the outbreak might have been attributed directly to an artificial infection. In fact, it seemed to Mr. Metcalf, at least at first, that the fungus he had sown was quite successful, especially as he had put it out before any appearance of diseased bugs was manifest. But spontaneous outbreaks occurred in all the fields examined around Cherryvale at about the same time, and no difference was noticed as to whether a field had been artificially infected or not. One can readily see how a farmer, observing the state of affairs merely on his own place, would be convinced of the success of his artificial infection and would send in his report accordingly.

So plausible was the evidence to Mr. Metcalf that it was only with difficulty that he was convinced after visiting a check field owned by Mr. Steinburger and located $1\frac{1}{2}$ miles distant. The Steinburger field was nearly as badly infested as was Mr. Metcalf's, and the diseased bugs appeared more numerous than on his own, though no artificial infection had been used.

On this date (May 26) the Metcalf field was artificially infected by fungus culture for the third time. The amount of fungus added to the field was, of course, a small proportion of that found naturally on the thousands of dead bugs scattered through it. On June 23, about harvest time, the field was again visited. Conditions were found to be about the same as on the previous visit. Two check fields other than Mr. Steinburger's, lying about 2 miles distant, were used for comparison. Both had numerous living bugs and as extensive spontaneous outbreaks of *Sporotrichum* as any field around Cherryvale.

Montgomery County, Independence.—The experiments conducted at Independence were under the supervision of Leslie A. Kenoyer, a graduate in science of the University of Kansas. Mr. Kenoyer lived at home, on the farm, while carrying on his work, and was therefore able by constant residence to watch the progress of events in a most satisfactory manner. His observations, however, were checked up from time to time. His final report is given below in full.

MR. L. A. KENOYER'S REPORT OF HIS EXPERIMENTS WITH *SPOROTRICHUM* AND
THE CHINCH BUG.

My observations on chinch bugs near Independence, Montgomery County, Kans., covered a period of nearly three months—from March 20 until June 14, 1910.

The bugs were found to occur in most grain fields. They were, as a rule, most abundant near the borders of the field, and especially adjoining hedges of Osage orange. These hedges are numerous in this county and they appear to be excellent harboring places for the bugs, chiefly, it appears, by reason of the weeds and grass which collect there. Even spring burning does not seem to destroy the bugs.

Dr. F. H. Billings and I planted bush beans around several selected plots of grain about April 15. The plots chosen were 50 feet square. A trench 1 foot wide was made around each and four similar trenches were placed across the square at intervals of 10 feet—the whole having the form of a gridiron. The beans were thickly sown in the trenches. In the Evans and the Page wheat fields two plots in each were thus arranged, the one to be infected and the other to serve as a check. In the Kellenberger oat field one plot was planted and kept infected. In the Evans wheat field two plots of the same size and appearance as those planted to beans were laid out by means of strips of old straw 1 foot broad. One was infected and the other left as a check. In a neighboring field small piles of straw and of fresh weeds were placed at intervals and kept infected.

The end sought in these experiments was a method of supplying shade and moisture enough to encourage the development of the fungus.

Fungus grown at the University of Kansas on a preparation of corn meal and potato extract was pulverized, mixed with dry dust or sand, and scattered in the bean rows and strips of straw.

In the Page field the plots were planted just south of a hedge, along which were a good many bugs in the spring. The plots were about 60 rods apart. The west one was infected May 7 and May 14. As the bugs seemed to diminish in numbers along the hedge, no more fungus was placed in this field. At the last examination, June 11, a few living and a few fungus-covered bugs were found in both

places. Both living and dead seemed to be rather more numerous in the noninfected plot, but the results were indecisive.

Fungus was sprinkled on the bean plot in the Kellenberger oats field May 7, May 14, May 26, and June 4. Bugs did not become plentiful in this field and very few young ones appeared. There were a few more, both living and diseased, in and about the infected plot than elsewhere. But wherever there were living bugs, diseased ones could be found by a little searching.

In the Evans field the bean plots were located just north of a hedge and about 40 rods apart. The east plot was infected on the above-mentioned dates. Bugs continued very numerous all spring in this field. Hordes of young ones appeared about the middle of May and their influence, added to that of an early spring drought, killed much of the wheat before it was ripe. Fungus developed all over the field so freely that by the middle of June from 50 to 100 dead and whitened bugs could frequently be found around the bases and on the roots of a single hill. While the fungus appeared in all parts of the field it was in general more abundant at the west end, so it chanced that the uninfected bean plot showed decidedly more fungus than the infected one.

The "east" straw plot was infected on the same dates as the bean plot and the "west" plot was left as a check. On neither one were the bugs as numerous as along the side of the field on which the beans were planted, but both living and dead bugs were to be seen in about equal numbers in the infected plot and the check plot.

The piles of straw and those of weeds were likewise infected, but without any appreciable increase in the death rate of the bugs.

Although the beans had made a very good shade before harvest time, the bugs showed no marked tendency to seek the shade. They are more active on sunny days than in cool, cloudy weather, and when crawling from hill to hill they appear to seek sunshine rather than shade.

After the wheat had ripened the bugs crawled up the bean bushes in considerable numbers, and many dead fungus-covered bugs could be seen adhering to the leaves of the plants and to the young beans. Famine had evidently aided the plague in this case. But here again there was no difference in favor of infected portions.

To determine the efficiency of the distribution of dead bugs in fields I selected an oats field on the Evans farm, one-fourth of a mile from the experimental wheat field. A strip of about 3 by 10 yards was sprinkled on May 25, May 28, and June 4 with diseased bugs grown in culture boxes. Developments on this portion were in no way different from those on the remainder of the field.

On April 20 a pint fruit jar was scalded and half filled with bugs and soil from the Evans wheat field. *Sporotrichum* developed in

from 8 to 10 days, showing quite conclusively that the spores were present in the soil.

In a field of wheat and in one of rye, west of the infected fields and about three-fourths of a mile distant from any of them, diseased bugs were found in the early part of June in as great numbers as in the Evans field just mentioned. The chance of material from my infections having reached these fields was very improbable. Several other fields were examined and none was free from infected bugs where bugs were plentiful in the period preceding harvest. But the proportion of diseased bugs varied considerably from field to field. And apparently in no case had the fungus produced an epidemic sufficient to materially reduce the number of bugs or to save the crop.

My experience with infection boxes was not such as to greatly encourage the infection idea. Living bugs were confined with diseased ones in boxes of moist earth for weeks at a time, and only a very few became infected. Later in the season, when the disease became common in the fields, it spread more readily in my boxes.

My observations lead to the following conclusions:

1. *Sporotrichum* occurred naturally in the soil of all of the fields.
2. The distribution of the spores or of spore-covered bugs in a field had no noticeable effect upon the dying of bugs.
3. Bugs died spontaneously when the weather was sufficiently moist and when the ripening of the grain diminished their food supply.
4. Spontaneous infection did not spread to such an extent as to materially benefit the crop.

The results attained in the preceding report were confirmed by observations made during the experiments. The results fully accord with those obtained elsewhere, and are of particular value because of the favorable moisture conditions and the larger number of chinch bugs. In the Evans field the young bugs suffered more severely by attacks of the fungus than in any other field investigated.

Weather conditions for Cherryvale and Independence.—The weather statistics for these two centers of experimental work were gathered by Mr. F. L. Kenoyer, of Independence, and we hereby express our thanks to him for his kindness in taking humidity readings and furnishing a copy of the precipitation record. During the month of May and the fore part of June, southeastern Kansas had a rainfall in excess of the average and a relatively high humidity. The soil in this section, being mostly heavy, retained the moisture well. The conditions for fungus propagation seemed to be ideal during a part, at least, of the period of growth of the new brood of chinch bugs. While adults seemed to succumb first, many young were affected, especially at Independence.

The total precipitation at Independence for the months of April, May, and June, 1910, was 10.97 inches, which was 4.70 inches in excess of that of Rome (near Wellington, in Sumner County). The rainfall for May alone at Independence was 6.25 inches, or about the same as for the three months near Wellington. The May precipitation was 6.25 inches, or 1.44 inches in excess of the average. In addition to the unusual total precipitation for this month, the rainfall was well distributed. There were 19 cloudy days in May, and 5 partly cloudy, so that the month was damp for most of the time. Conditions were very favorable for *Sporotrichum* from the first week in May until the harvest time, and it was certain that the fungus responded by attacking vigorously both young and old bugs. Notwithstanding the favorable conditions, there were plenty of bugs left at harvest time—enough to do great injury to the corn.

Anderson County, Colony and Garnett.—The experiments of Colony only will be outlined below. Two fields were used for experiment, but the field notes taken on Mr. Quiett's place will suffice for the purpose.

Experiments on Mr. W. A. Quiett's place.—Work began on Mr. Quiett's place on April 20, when a field of wheat was searched for diseased bugs. While none was found, living bugs were numerous, and two bottles of bugs and earth were collected to see if *Sporotrichum* would develop spontaneously. The results were negative. Diseased bugs were left with Mr. Quiett, so that he might start an infection box. On May 3 a supply of fungus culture was sent for field infection. It was distributed along the north side of the field. On May 19 the field was examined for results. Two diseased insects were found on the north side near the infected locality, but none was seen on the south side. It was evident, as in the Boone field, that no spontaneous outbreak had occurred. Some of the fungus had been placed under piles of straw, but there were no results in dead bugs. There had been more or less rain for about three weeks and the soil was wet. Another visit was made May 26, with no change in the condition of the field. Weather was cool and damp. Some fungus was placed at the base of the wheat in a small patch that was carefully marked. A similar patch some distance away was infected with diseased bugs and also marked. Some living bugs from the field were caught, shaken in a box with *Sporotrichum* spores, and then turned loose under a bunch of straw. The experiments on this date (May 26) were concluded by leaving a quantity of the fungus culture with Mr. Quiett for further field infection. The next inspection took place June 21. All parts of the field were searched for diseased bugs. Extremely few were found, and no more around the infected spots than elsewhere. The ground was damp and shaded in some places, but there were no more in evidence in

one place than in another, so far as could be seen. Harvest had begun before another visit was made, on July 12. The bugs had gone into some adjacent corn. Pupæ were very thick on the ground about the base of the stalks, under bunches of crab grass and other vegetation that afforded protection. Adults were emerging in large numbers. A few diseased bugs were found in the corn where the bugs were collected for molting. A pile of cut corn was made in the field and fungus scattered in it. A second pile was made and left uninfected. On July 30 an inspection showed that diseased bugs were still scarce, only one being found. The infected and check piles of cut corn and the locality immediately adjacent showed no effects of the infection or shading. Both piles of corn contained thousands of molted skins of the bugs, which might have been taken by an unskilled observer for dead bugs.

Results of experiments in Anderson County.—Conditions at Garnett and Colony were unique when compared with all the other places where experiments were made. Spontaneous outbreaks of *Sporotrichum* had been the rule, but at Garnett and Colony they were absent, or nearly so. To explain the situation, one would naturally examine the climatic conditions, since they probably have more to do with the propagation of *Sporotrichum* than any other factor. The following table gives some comparative data:

Place.	May and June.	
	Precipitation.	Mean temperature.
	<i>Inches.</i>	<i>° F.</i>
Garnett.....	11.31	65.5
Oswego (Parsons).....	9.61	68.0
Lebo.....	12.46	65.6
Rome (Wellington).....	4.67	68.8
Lebanon.....	6.19	65.1
Chanute (Thayer).....	13.69	65.5
Independence.....	9.21	68.1
Hutchinson.....		67.1

Garnett had an abundance of moisture, but the spontaneous outbreak was only slight. Conspicuous outbreaks occurred at Lebo and Thayer, where the precipitation was greater, at Parsons and Independence, where it was but a little less, and at Wellington and Lebanon, where the precipitation was much less. The mean temperature for the two months was below normal, but not below the mean temperature of other places where spontaneous outbreaks occurred, for example, Lebanon and Thayer. It would seem, therefore, that the explanation of the fact that spontaneous outbreaks in Anderson County were so meager can not be found in the climatic condition, and must be attributed to some other factor. Was it due to a scarcity of fungus naturally present in the soil? This would seem to furnish

a plausible explanation at least, since our tests in nearly every case yielded negative results. But when large quantities of the fungus were introduced the results remained unchanged; no epidemic could be started. It seems evident, therefore, that the failure of an outbreak to occur was not always due to the lack of the fungus, but to some other factor as yet unknown.

If these two places in Anderson County are representative of those in which spontaneous outbreaks do not seem to occur, then it is evident that artificial infection does not produce such outbreaks or any beneficial effects that are commensurate with the amount of fungus introduced and the time and expense necessary in introducing it.

Corn-infection experiments at Cherryvale.—The field work at Cherryvale was more extended than at Independence and the climatic conditions were more favorable, especially during the first part of the work. The fields selected were owned by Mr. Metcalf and Mr. Botkins. They were separated by a wheat field, from which chinch bugs migrated. By the 21st of June about the first 20 rows of corn were badly infested. Two plots of corn were selected in the Metcalf field, at opposite ends of the corn rows nearest the wheat. The plots were surrounded by ridge barriers on which crude oil was placed. Each area had about as many bugs in it as the other. Both were very badly infested, and the corn gave promise of being quickly killed unless the bugs were exterminated. One of the plots was artificially infected with fungus culture. The spores were mixed with earth and dusted on the bugs. Some of the dried cultures were used without an admixture of earth. The insects swarmed on the corn in such compact bunches that large numbers could be easily dosed with fungus spores. Practically all of the bugs in the plot had an application of *Sporotrichum*. The other plot was used as a check. Each plot was about 40 feet long and included three rows of corn. The experiment continued for a week, or until the corn was completely killed out. The bugs were unhurt and finally escaped over the barrier and scattered into the new corn.

A new type of experiment was then tried, the chief merit being the maintenance of extremely humid conditions. The other factors, large numbers of bugs and intensity of infection, were still at hand. The experiment consisted of cutting corn badly infested with bugs and piling it in heaps, bugs and all. In the Metcalf field about a dozen stalks composed each. The top soil under each pile was removed to expose the damper subsoil, which thus assisted in preserving the dampness. The bugs repaired to the lower portions of the piles as soon as they were made, and there, with the moisture from the leaves, from the ground, or from the rain, or artificial watering, the humidity was high enough to insure propagating of the fungus.

In the Metcalf field six piles of corn were laid. Two were well watered and two of the remaining four were covered over with rank weeds to increase the shade. The last two were not watered nor covered with weeds. All were thoroughly infected throughout with *Sporotrichum*. Chinch bugs swarmed inside the piles and as long as the corn remained reasonably fresh they apparently made no effort to leave.

A similar series of piles was constructed in the Botkins field, only they were larger, having 40 stalks to the pile. A dozen such heaps were made, and they were about 60 feet apart. None of the piles in the Botkins field was artificially infected.

Four questions were to be decided by the corn-pile experiment: (1) Would the chinch bugs become diseased in an uninfected pile? (2) Would they become so in an artificially infected one? (3) Would the infected bugs leave the piles and carry the contagion to other parts of the field and ultimately bring on an epidemic? (4) Would the bugs die by sucking the juice of the corn, soured after cutting, as had been stated by certain farmers?

The piles were prepared June 22. Heavy rains occurred June 25 and 27, making the ground very muddy. Diseased bugs were noticed around the base of the corn in various parts of the field. The piles of cut corn were examined and a few dead bugs were found. The corn was very wet, and the lowest stalks and leaves in some of the piles were in mud. As the greater part of the leaves were still fresh, the bugs had not left the piles, but seemed quite as numerous as ever. If the juice had soured it had thus far caused no perceptible mortality among them. Molting had occurred to a considerable extent, and the old skins resembled dead bugs sufficiently to have probably caused some of the farmers to mistake them for bugs killed by sour juice or by *Sporotrichum*. The piles in the Botkins field, although untreated, contained more diseased bugs than the artificially infected ones in the Metcalf field. Conditions were probably more favorable in the former than in the latter case, since the corn was piled on higher ground and did not get so soggy.

Thus far no effect worth mentioning from *Sporotrichum* was observed in any of the piles. The diseased bugs in the piles on the Botkins place served as infection for the other bugs. It seemed as though conditions in this field could not have been made better for the spread of infection, yet the number of diseased bugs was only a very small fraction of the living.

On this date (June 27) a pile of freshly cut corn infested with bugs was made in each field, the one on the Metcalf place being infected artificially with *Sporotrichum*. All of the piles were examined on July 6. The original ones (made June 23) were found

to be deserted by the bugs, and the corn dry and in some instances moldy. Skins of molted bugs were very numerous, and *Sporotrichum*-covered carcasses were in considerable abundance, but aside from the latter there was no evidence of dead bugs, i. e., that might have been killed by sour juice, for instance. Evidently the great majority had migrated, leaving comparatively few dead behind as the result of infection by fungus.

The corn piles made on June 27 were in good condition, the corn being green and fresh. Chinch bugs still swarmed through them in multitudes, and there were old skins and quite a number of diseased bugs. There were a few more diseased bugs in the Metcalf corn pile than in that in the Botkins field, and the difference may have been chargeable to the artificial infection. The percentage of diseased insects when compared with living, however, still remained very small, so that as an effective means of propagation of *Sporotrichum* disease, the corn piles were a comparative failure. Quite the reverse might have been expected, since the chinch bugs remained exposed for over a week to infection under shade and moist conditions. With negative results under such circumstances artificial infection could hardly be expected to work in the open field. Almost every chinch bug in the corn piles must have come into contact with the fungus spores sooner or later, especially where artificial infection was used. After leaving the piles the bugs transported the spores to various parts of the field, but there was no evidence that the spores took effect.

By July 6 nearly all of the corn in the full 50 rows was destroyed. Infection of chinch bugs on corn by the use of fungus culture was made on this date and again on July 17. Cultures mixed with earth or used directly were employed in dusting spores on the insects. Final observations were made on July 28, five weeks after the first lot of the fungus was sown in the corn. From a practical standpoint everything was negative. At no time did the *Sporotrichum* disease appear to be working except in the smallest way. Perhaps the weather conditions were not just right, but at Cherryvale they were apparently right for at least part of the time and that long enough to have started an epidemic.

If the relation between climatic conditions and successful fungus propagation, however, is so exact that not once did anything like a really destructive epidemic occur during all the series of experiments and observations from April till nearly the first of August, then farmers should not for a moment think of depending on artificial infection or on the fungus disease at all for the saving of their crops. Whatever good had come from *Sporotrichum* as a destroyer of chinch bugs came of itself without the aid of artificial sowing of spores.

REMEDIAL MEASURES AND CONCLUSIONS.

The University of Kansas, during 1910, sent out 1,363 packages of diseased chinch bugs at the request of farmers, with which to start infection boxes and artificially infect their fields. The plan followed was in accordance with recommendations of Dr. Snow, who in the nineties attempted to check the ravages of chinch bugs by the distribution of *Sporotrichum globuliferum*, the cause of the well-known white-fungus disease. A series of investigations, however, was inaugurated early in the year 1910, and continued until nearly the first of August, the purpose being to ascertain the practicability of artificial infection.

The plan of work embraced the solution of the following problems: (1) Determination of the extent of the presence of the chinch-bug fungus naturally in Kansas soil, (2) practicability of artificial infection of fields after the fungus was already shown to be present, (3) practicability of artificial infection of fields containing apparently little or no *Sporotrichum*, and incidentally (4) ascertaining so far as possible the best method of fighting chinch bugs in case it were proved that artificial infection with fungus is not effective.

The work of solving the first problem fell naturally into two divisions, namely, (1) examination of chinch bugs for the fungus disease, while they were still in winter quarters, and (2) examination of chinch bugs for disease after migration to wheat or corn fields.

While gathering data for determining to what extent *Sporotrichum* was naturally present in Kansas soil, many localities in the infested area were visited. The work began in January, 1910, and extended well into the summer. As a result, 59 counties of the State were found by direct personal observation to contain the fungus. These counties are so well distributed over the infested area of Kansas as to leave but little doubt that those intervening are likewise supplied with fungus.

The widespread occurrence of *Sporotrichum* over the State was recognized near the close of Dr. Snow's investigations, in the nineties, since in one of his later reports (the fifth) we read the following: "We may conclude from the experiments that *Sporotrichum* was pretty generally prevalent throughout the State, and that probably in many localities there was no necessity for its artificial distribution in 1895."

The prevalence of the chinch-bug disease in Kansas soil once established, the next question was the practicability of sowing more fungus in fields known to contain it naturally. A solution was sought by actual field experiments in which relatively large quantities of fungus were used, sometimes on entire fields, other times on small plots where, in consequence, an intensive artificial application

of the infection resulted. While diseased chinch bugs were used to some extent in artificial infection, they proved inadequate because of the small amount of fungus available. Spore material for field work was generally obtained from cultures grown on a mixture of corn meal and potato extract. By the use of this medium large quantities of fungus were propagated in the laboratory. Its spores were tested from time to time in order to be assured of their power to produce disease in living chinch bugs.

With the exception of the experimental fields in one county (Anderson) there was already an abundance of *Sporotrichum* naturally present in the soil, as manifested by the whitened carcasses of its victims. These were generally in such large numbers and were so widely distributed that it seemed utterly futile to add any more fungus, since it was such a trifle by comparison. Nevertheless, 19 experimental fields, distributed over 5 different sections of the State, were treated with *Sporotrichum* spores. In some the artificial infection was confined to small plots of wheat 50 feet square, with the expectation that the intensive infection would start an epidemic of the disease that would spread and kill a large proportion of the bugs. But no results were forthcoming, for not only did the plots fail to become centers of contagion, but there was little or no appreciable difference between the treated and the untreated, or check plots, which were always used as a basis of comparison. General field infections were likewise always failures.

Considering the 19 localities as a whole, there were all sorts of conditions of humidity and rainfall, also character of soil. The results, however, were always the same—never at best any more than a slightly appreciable effect due to sowing spores and never more than a small percentage of the bugs killed. The bugs victimized by the fungus were as numerous in an untreated plot or field as in a treated one, the numbers bearing no relation whatever to artificial infection, but rather to climatic conditions, shade, moisture, etc. The evidence in every instance was overwhelming against the artificial use of fungus, as being without effect, and hence useless, since the fungus naturally found in the soil really accomplished whatever destruction of chinch bugs there was.

The third problem to be solved was the practicability of artificially treating a field with *Sporotrichum* when the fungus was shown to be scarce or, at least, ineffective. Three fields—one at Garnett, the others at Colony—were of this sort, and the bugs in all of them were liberally dosed with fungus. Small areas were treated as well as entire fields, and diseased bugs were used as well as culturally grown fungus; but scarcely any effect could be made, as measured by mortality among the bugs. No epidemic could be started nor the death rate appreciably increased, even in marked spots that were given specially large amounts of infection.

Conclusions from all the experiments may be summed up as follows:

1. The chinch-bug fungus is present naturally in fields everywhere throughout the infested area in Kansas.

2. It is present in such great abundance that any artificial distribution of infection in a field would be too insignificant, by comparison, to be of practical use.

3. Its distribution naturally through a field is much more uniform than any artificial distribution can be made.

4. The amount of fungus used experimentally in both wheat and corn fields was so far in excess of any that would be used by the farmer in infecting his own fields that he could not reasonably expect to succeed.

5. The fungus shows little tendency to spread from centers of artificial infection. The apparent rapid spread of the fungus is due to favorable conditions bringing it into activity simultaneously over considerable stretches of territory.

6. In fields where the natural presence of the fungus is plainly evident its effect on the bugs can not be accelerated to any appreciable degree by the artificial introduction of spores.

7. In fields where the fungus is not in evidence spores introduced artificially have no measurable effect.

8. Apparent absence of fungus among chinch bugs in a field is evidence of unfavorable conditions rather than lack of the fungus spores.

9. All the benefits of the *Sporotrichum* disease of chinch bugs may be realized by merely letting the fungus naturally present in the soil do the work of extermination as far as it will.

10. Moisture conditions have much to do with the appearance of chinch-bug disease in a field; artificial infection nothing.

11. Spent adult chinch bugs succumb to attack more readily than younger ones, but as the old bugs have finished depositing their eggs, their loss by fungus disease accomplishes little else than increasing the amount of the infectious material.

12. Laboratory experiments can be made to prove that artificial infection accomplishes results upon bugs confined in cramped quarters and without food, but in the field, where fresh and usually drier air prevails and food is abundant, an entirely different situation is presented.

13. Advocating artificial infection or encouraging it by sending out diseased chinch bugs does not serve the best interests of the farmer, since his attention is thus diverted from other and more efficient methods of combating the pests.

14. The reported successes of former years on the part of farmers are believed to be due to the following causes: (1) Failure to recognize spontaneous outbreaks of the disease because of previous arti-

ficial sowing of infection, and also failure to use check, or untreated, fields as a basis of comparison, thus claiming the outbreak as directly due to artificial infection; (2) failure to distinguish the skins of molted bugs from dead bugs; (3) mistaking the scattering of chinch bugs in cornfields for evidence of their death by fungus disease when carcasses were not present as proof.

Approved methods of combating the chinch bug.—The long-drawn-out fight against the chinch bug has brought to light many methods of combating it, which, when properly applied, have proved very beneficial; but the farmers are very busy men and can not devote a great deal of time to this work, and for this reason it seems best to speak only of methods which have proved the most practical. We can not hope to exterminate the chinch bug from any given district by any artificial methods now known; we must depend upon natural causes to do that, but in the meantime we can do much to stay their ravages. Their numbers can be greatly reduced and valuable crops protected from their depredations. The failure to control these and many other pests is not to be ascribed to the lack of practical means of control, but rather to the failure on the part of farmers and fruit-growers to avail themselves of the methods of control which have been worked out, and especially in the case of the chinch bug to the failure to secure concerted action throughout the area of infestation.

The two seasons when practical measures can be applied are: The fall, after the chinch bugs have gone into their winter quarters, and the summer season, at the time when the bugs are leaving the grain fields or immediately after they have massed themselves upon the first rows of corn.

Fall treatment.—Since the chinch bugs winter as adults in grassy places and in rubbish of all kinds, grasslands, and weed patches, every place where there is a possible chance for them to winter over should be burned off in the fall after they have gone into hibernation.

From observations made during 1910 while collecting bugs from their winter quarters, it was quite definitely determined that the bugs very much prefer bunch grass to anything else as a place to pass the winter, and where such grasses are growing along fences and roads adjoining cornfields they will be found to harbor vast numbers of bugs. So, if it is impractical to burn off all grasslands, those adjoining cornfields should, at least, be burned.

The burning does not necessarily kill the bugs, for they work down into the roots of the grass, where the heat caused by the burning is not sufficient to kill them, but those that escape the burning are left much more exposed to the effects of changes in temperature throughout the winter months and are likely to perish before spring. The drier the ground is when the burning is done the more effective will it prove, for when the ground is dry the grass will burn off closer

to the ground, more of the bugs will be killed outright, and the protection for those that escape will be more effectively removed. The burning should not be done too early, for in that case, unless every place where they might hibernate is burned, those bugs that escape destruction by the fire will have an opportunity, during the warm days that follow, to seek a new shelter. If the burning is delayed too long we are apt to have bad weather, which will interfere. About the latter part of November or the first of December is usually a good time. This is the time when there is a great need of concerted action. It will do little good for a farmer here and there to burn, if others do not. No consideration should prevent farmers all over the infested area from applying the torch in the fall or early winter.

Systematic burning is not to be recommended every year, for a large number of our most useful insects seek the same places to hibernate as the chinch bugs, but in years when the chinch bugs are apt to prove disastrous the good to be derived from destroying them in their winter quarters will by far outweigh the loss of some of our beneficial insects.

Burning in the spring will do little good, unless it should be very dry and the burning be done at just the right time. The only good that can result from burning in the spring will come from the bugs actually destroyed by the burning. If the burning be done too early, while the ground is still frozen, or later, when the ground and grass is very wet, very few bugs will be killed, but should the ground and grass be dry and the burning be accomplished between the time when bugs are beginning to come up out of the roots of the grass and move about, and before they begin their spring flight, large numbers will be killed. The most favorable time in the day for burning, either in fall or spring, is from 10 o'clock in the morning to 3 o'clock in the afternoon. If the burning is done in the night, as is often the case, the bugs will have descended into the roots of the plants again, and a smaller number will be killed outright.

Summer treatment.—After the bugs have become established in grain fields in the spring there is no practical way of destroying them. The best that a farmer can do is to hope for warm, wet weather during and following the hatching season in May and June, and prepare to take up the fight when they begin to leave the wheat fields. In making preparations for this fight the farmer should provide himself with a quantity of coal tar from the gas works, or No. 18 residuum asphaltum, or crude oil from the oil refinery, and either a knapsack spray pump or a spray pump mounted on a barrel. These should be provided before harvest begins, for sometimes they can not be procured without delay, and if this fight is to prove effective there must be no delay at the critical period.

The dust barrier.—The plan of the fight will necessarily depend on the conditions of the weather. If it should be warm and dry at harvest time the farmer should erect a dust barrier around the entire field containing the bugs, as follows: Before any of the wheat or other grain is cut, or, better, immediately after the first few rounds have been made by the binder, plow a strip around the field about 8 feet wide. This should be harrowed or dragged to pulverize the soil; then in the side of the strip farthest from the inclosed field a deep furrow should be thrown out with a lister, making round corners, and a log about a foot in diameter and 6 feet long, to which a single horse is hitched, should be dragged around the field during the day as long as migration continues. If it is very hot and dry many of the bugs will perish in their efforts to cross the dust barrier lying

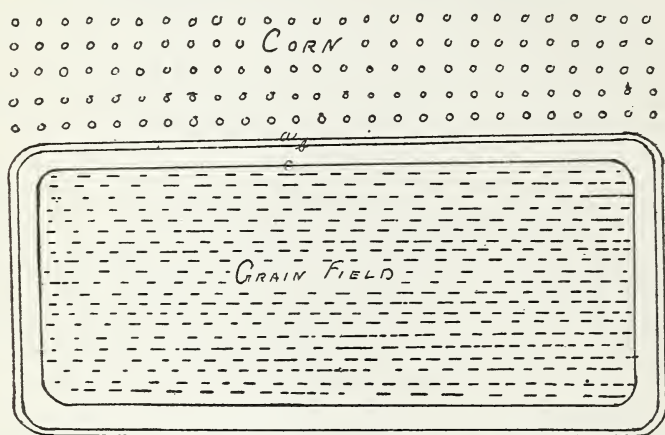


FIG. 3.—Diagram illustrating the construction of the dust barrier. *a*, Outer edge of dust barrier; *b*, furrow; *c*, inner edge of dust barrier. (Original.)

between the field and the furrow, and those which succeed in getting into the furrow will not be able to crawl up the dusty sides to get out. Many of them will be killed by the heat, and those that escape will be crushed by the log or smothered by the dust of the furrow. The log should pass along frequently enough to keep the bugs from making breaches in the dusty sides of the furrow by their constant endeavors to climb up. If one log does not prove sufficient two or three may be used, as needed.

If the weather should remain warm and dry during the whole time when the bugs are leaving the field the above method will be sufficient in most cases. This method, with perhaps a little difference in the details, has been found to be very effective, and has the advantage of being inexpensive and devoid of details which are necessary in other barriers, and it is, therefore, recommended when the weather is dry and hot.

Oil barriers.—If the weather should be wet, or if light showers should occur, so that it is not possible to keep the surface of a dust barrier pulverized and dusty, the farmer may resort to the oil barrier.

The type of the oil barrier used in past campaigns against chinch bugs is the earth ridge, with a small line of coal tar on top. It has been thoroughly tested, and if properly maintained will prove effective as a means of trapping and destroying the bugs in large quantities.

The plan found most effective is that of turning a double furrow with a plow, and thus forming a ridge, and putting tar, etc., on top of this ridge. On the side of the ridge next to the small grain, postholes about 75 or 100 feet apart and 2 feet deep are dug. The bugs are thus retarded in their march by the ridge, and, being repelled by the tar, etc., swarm along the ridge and crowd each other into the postholes. When the holes are nearly filled with bugs dirt should be thrown in and tramped down, and new holes dug to take their places.

After the ridge is thrown up by the plow the top should be smoothed off and packed down so as to hold the tar or oil which is poured thereon. The sides of the furrow should also be smoothed so as to make it difficult for the bugs to climb up. This can be done with a hoe and a rake, but it is much more quickly done by using a drag made with a concave bottom of the form of the desired ridge. This should be heavily weighted and drawn by horses along on top of the ridge. Such a drag is easily constructed and will save much time and do better work than can be done with the hoe and rake. The bottom of the drag will scour better if covered with sheet zinc.

Coal tar as it comes from the gas works is the best thing known for this type of barrier, as it does not sink into the ground readily and is very effective against the bugs. No. 18 heavy residium asphaltum from the oil refinery was tried as a substitute for the tar in one of our experiments conducted during the past season and gave excellent results. It stands next to coal tar in its efficiency, and costs about the same. It could be procured at the refinery last summer at \$4 a barrel. It will require about one barrel of the tar or asphaltum for every 80 rods of barrier constructed. Crude oil was also tried, and while it was effective for a time after being applied, it soaked into the ground very readily and had to be renewed frequently. If crude oil is used, about twice the amount given for the coal tar will be needed. The cost of crude oil at the refinery (including barrel) was \$1 in 1910.

Whichever one of the above repellents is used, it may be applied by using an old teakettle, coffeepot, or sprinkler with the perforated end of the spout removed. In applying the tar or asphaltum

the operator should move along fast enough so that the line deposited on the ridge is about an inch wide.

The ridge should be thrown up and the postholes dug before the migration begins, leaving the application of the repellent until actually needed.

The oiled-ridge type of barrier has the advantage of not being dependent upon a complexity of conditions for its success, and of giving immediate results. However, in dry, windy weather, when much dust is blowing, the dust is apt to stick to the tar or asphaltum in quantities to render it inefficient. For this reason the dust barrier is recommended for dry weather.

After the barrier is formed it should be inspected daily and kept in good repair. The tar will have to be renewed occasionally and the barrier kept free from straws or débris which might fall or blow

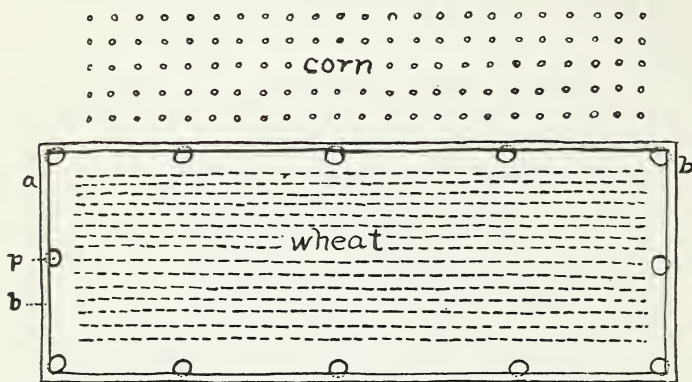


FIG. 4.—Diagram illustrating the oiled-ridge type of barrier—b, barrier; p, postholes. A partial barrier between the wheat and corn would extend from a to b. (Original.)

upon the ridge and form a bridge over the repellent stream for the chinch bugs to cross. Eternal vigilance will be the price of success.

The crude oil-straw barrier.—An experiment was tried in which straw dipped in crude oil was used as the repellent part of the barrier. It gave promise of success, especially when small fields were to be protected. To erect a barrier of this kind the farmer would need, besides the straw and crude oil, a tube or barrel mounted on a sled or wagon, a pitchfork, and a posthole digger. The oil is placed in the barrel or tub and the straw dipped into it and laid in a long windrow about a foot wide and from 4 to 6 inches high. This is the barrier. Postholes are dug on the wheat-field side of the barrier about 75 feet apart and so that the straw somewhat overhangs the edges of the postholes. Loose soil or air-slaked lime on the sides of the openings facilitates the fall of the bugs into the postholes.

The advantages of the oiled-straw barrier are its cheapness and the fact that it is not easily affected by weather conditions. Heavy

rains tend to wash the oil off, but it can be renewed easily with a garden sprinkler. Under ordinary conditions the original oiling will probably suffice.

The volatile products of the oil keep the bugs from crawling beneath the barrier, and the difficulty of crawling along straws lying in every direction and coated with the offensive-smelling oil discourages the bugs from their attempts to crawl over.

It is to be regretted that the oiled-straw barrier was not thought of soon enough to make a test of its practicability in protecting an entire field. A small patch of corn in a field into which the invasion of the bugs had already begun was surrounded by a barrier of this kind in order to ascertain its effectiveness. A few bugs were already in the corn inclosed by the barrier, but these were removed by hand and thrown outside. Any bugs that were subsequently found in the corn, therefore, presumably had crossed the barrier. The experimental corn patch lay in the direct line of march of the principal mass of migrating bugs.

The barrier was prepared June 23, 1910. During the next five days no fresh oil was applied, and a torrential rain washed out some of the oil with which the straw was originally saturated, leaving the upper straw odorless and reducing the oil beneath, so that the odor was faint. As a result, a few chinch bugs were found crossing the barrier on the uppermost straws. None was passing underneath. A second application of oil was made with a garden sprinkler. Had it been made immediately after the rain, probably no bugs would have crossed the barrier. No further application of oil was made. The field was inspected July 6. Only a trace of rain had fallen in the meantime, and the barrier had retained the odor of the oil, and consequently retained its effectiveness throughout the remaining period of the attack.

The bugs within the inclosure were so few in number that no material damage was done to the corn, and consequently the stalks had made a nearly normal growth and presented a striking contrast to the corn outside of the inclosure, which lay withered on the ground. No postholes had been dug, so that the insects encountered the barrier, passed around it, and then straight on into the corn beyond. A few, however, turned into the corn back of, and protected in part by, the inclosed patch. But as they did not damage it much, it grew and appeared nearly as vigorous as the corn within the barrier. By July 28 the chinch bugs had scattered, but they had left a trail of destruction in their path, all the corn being killed except the small patch protected by the oil-straw barrier and the corn immediately back of it and an occasional stalk here and there which had escaped serious injury. (See Pl. V, fig. 1.)

A barrier inclosing a field versus a barrier along one side only.—Barriers are usually erected only between the field from which the

bugs are about to migrate and the field to be protected. Such barriers are of value in preventing the injury caused by the massing of the bugs in the proximal side of the field into which the bugs are endeavoring to migrate, and by permitting destruction to a vast number of the invading host, but it should be remembered that when a field of grain that is infested with chinch bugs is harvested the bugs leave in all directions.

If the barrier is erected along one side of the field only, the bugs which escape from the other sides of the field manage to live on grasses and other vegetation, which usually can be readily found, until they get their wings, when they take wing and finally get into the corn. They not only injure it, but raise another brood, the adults of which pass the winter and come out in the spring to continue their ravages. Just before harvest practically all the chinch bugs in any community will be found in the grain fields, and if each one of the grain fields in the community were surrounded by an effective barrier such a large percentage of the bugs could be destroyed that the community would be rid of bugs in injurious numbers. If this could be done throughout the entire infested area there is little doubt but that the bugs could be successfully controlled and thousands of dollars' worth of damage prevented. However, a barrier along one side of a field is worth while and is to be recommended when for any reason it is not possible to erect it on all sides of the field.

Spraying.—It may happen that because of delay in getting an effective barrier up, the bugs get into the cornfield and mass themselves on the first rows. When this occurs the spray pump should be brought into use, and the bugs killed with kerosene emulsion or else with crude oil.

Kerosene emulsion.—The emulsion is made as follows: Dissolve 1 pound of laundry soap in 1 gallon of boiling rain water, then while hot add 2 gallons of kerosene, or coal oil, and stir vigorously with a stick for 10 minutes. The solution will soon take on a creamy appearance, but the stirring should be kept up for the full time. After the stirring is complete, from 27 to 47 gallons of rain water may be added according to the strength of the solution desired. By adding 47 gallons a 4 per cent solution is obtained, and Prof. Forbes and others have found this solution strong enough to kill most of the bugs and not injure the corn; but in our experiments this season we found that a 4 per cent solution did not kill the bugs to our satisfaction, and that the stronger solution, made by adding only 27 gallons of water, killed the bugs almost instantly and did not injure the corn to any extent when care was taken not to let the spray run down the inner circle of leaves at the crown. The important result to be obtained is the destruction of the bugs. As to whether the few rows of corn sprayed are injured or not, that is a minor consideration. If the bugs can be killed by the weaker solution and the corn saved, well



FIG. 1.—PATCH OF CORN PROTECTED BY THE OILED-STRAW BARRIER, AND SHOWING THE DESTRUCTION OF THE CORN OUTSIDE OF THE BARRIER. (ORIGINAL.)



FIG. 2.—CORNFIELD SHOWING CORN THAT WAS TREATED WITH CRUDE OIL. THE LARGE STALKS IN THE LOWER RIGHT FOREGROUND ARE IN THE ROW TREATED. (ORIGINAL.)



and good, but if the farmer finds that the bugs on the stalks sprayed are alive when examined an hour after being sprayed, he should use a stronger solution even if it does injure the corn.

Crude oil.—During the summer campaign an experiment was performed in Mr. Metcalf's field at Cherryvale, in which crude oil was applied directly to the cornstalks when they were badly infested with bugs. It was at first supposed that the oil might kill the corn; but it was found that, when applied to the lower portion of the stalks and the lower leaves, little or no harm resulted.

A field of corn lying north of a wheat field was exposed to a migration of chinch bugs. No barrier was used and consequently the bugs migrated into the corn. It was noticed that the great majority of the bugs were located on the stalks and lower leaves. A badly infested row was used for experiment and a checkrow, as yet uninfested, was treated in the same way. A bucket of crude oil was taken into the field and the oil dashed on the corn and the bugs with a bunch of coarse weeds gathered along the roadside. At the first stroke many of the bugs dropped to the ground, and the weeds were used to dash oil on them. Each hill in the row was liberally treated with oil and also the ground about the hill wherever the bugs were seen. The bugs were killed instantly and the oil protected the stalks from further attack. The two treated rows were watched for injury to the corn due to the oil. A personal inspection a month later showed no harm done, and a letter from the owner in the autumn declared that the rows matured corn in normal manner. The only precaution taken in applying the oil was to prevent the oil from getting into the crown of the young leaves. This method has not been tested thoroughly enough to warrant us in giving it our unqualified recommendation, but so far it has proved very destructive to the bugs and has not resulted in any material injury to the corn.

The use of sprays or crude oil should not take the place of barriers, but should be used as a supplementary measure only. (See Pl. V, fig. 2.)

The expense of making this campaign is very slight compared with the loss which the chinch bugs will occasion if not molested. The reasons mostly given by the farmers for not taking up this fight against the bugs is that they do not have time to bother with it. But if it is profitable to employ help to raise a crop it would seem that it ought to be profitable to put forth some little effort to save it after it is raised.

How to secure concerted action.—This whole subject needs to be agitated among the farmers. Township meetings should be called, the question discussed, and an organization formed for concerted action. At the first meeting called perhaps only a small number of farmers, the most progressive, will attend. With the organization formed, the agitation should be taken up by everyone interested. A time should be set for burning in the fall and efforts made to get

everyone to burn at that time. In the matter of summer treatment, the coal tar or crude oil could be ordered for a whole township at one time, resulting in a saving. Active preparation for the fight made by a large number before the time for the fight to begin will have a wholesome effect upon those who are lukewarm in their attitude toward it.

SUMMARY.

1. Organize by townships or school districts and counties.
2. Set a time for burning in the fall.
3. It is not practicable to burn off all lands where there are weeds and rubbish, burn at least all lands where there are tufts of grass, and especially if they are in close proximity to cornfields.
4. Before wheat harvest secure a good spray pump and at least a barrel of coal tar or No. 18 residuum asphaltum for every 80 rods of barrier to be erected about wheat fields, or two barrels of crude oil for the same amount of barrier.
5. If the weather is dry at harvest time, erect a dust barrier around the infested field. Plow deep so as to cover completely all the stubble and trash, harrow and drag, then throw out a furrow near to the outside border, and start the log as soon as the bugs begin to migrate.
6. If rain should come, fix up a tar or crude oil barrier around the infested field.
7. Spray bugs that escape to the corn with kerosene emulsion or apply crude oil.
8. Keep up the fight as long as the bugs keep coming from the field.

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